ANALYSES

Analyses

Project Design

This report includes a great deal of information about risks to the New Jersey environment. The manner in which this information was gathered and reported provides a better understanding of the project, its intent, its limits, and its potential applications. This section describes how the project was structured and includes background on many of the decisions that influenced the outcome of this report.

Project design

The basic steps in designing the comparative risk project included:

- √ Determining project scope and general decision structure
- √ Selecting and recruiting participants
- √ Structuring the Technical Working Groups
- √ Providing an analytic framework for the TWGs
- √ Designing mechanisms for public input
- √ Developing a problem (or issue) list
- √ Designing a risk ranking process
- √ Determining conclusions from the technical analysis

The responsibility for these decisions was in the hands of three groups, an informal DEP project coordination team, a Steering Committee of representatives from diverse sectors of New Jersey, and Technical Working Groups with expertise in different aspects of environmental risks. As noted in the introduction to this report, this project began as the result of a charge from the Commissioner of DEP.

Project scope and organization structure

A DEP **project coordination team**, under the guidance of the Director of the Division of Science, Research, and Technology, designed an initial project structure after reviewing the progress of other comparative risk projects in the country. An important element in this initial project design was its recognition of the necessarily limited role of DEP staff in accomplishing project objectives. External participation and decision making were recognized as being critical for ensuring that the project reflected the range of values of New Jersey citizens and ensuring credibility for the final product. In addition, external participation would greatly enhance opportunities for broad dissemination of project analyses and conclusions.

After establishing a preliminary scope for the project, DEP expanded its project coordination team to include Dr. Clinton Andrews from Rutgers University. Dr. Andrews brought additional experience with the comparative risk method to the project. An ongoing role of the project coordination team was to oversee staffing and to facilitate the operations of the Steering Committee.

The **Steering Committee (SC)** made the key decisions affecting the scope of the NJCRP. The SC was a diverse group of prominent citizens drawn from the spectrum of stakeholders interested in New Jersey's environment (Appendix 1). While a process for assessing risks could have been designed by a small number of environmental scientists, successful projects have benefited from a wider range of participants. This has helped to ensure that the project product reflected the values and needs of a cross section of citizens. The Steering Committee helped ensure that technical assessments resulted in environmental information useful for public deliberation.

A key responsibility of the Steering Committee was to take a leadership role in overseeing the process and products of the **Technical Working Groups (TWGs)**, including the incorporation of information from public outreach efforts into the TWGs' selection of issues and risk characterization parameters.

The Steering Committee made several decisions to set boundaries to the scope of the project. These include:

- Analyses of impacts only five years into the future (excluding longer-term impacts, such as those due to climate change from greenhouse gases) to minimize uncertainties of long-term extrapolation.

- A limit on the number of separate stressors (that is, biological, chemical or physical entities or substances that have negative environmental impacts; examples include parasites, lead, and radiation), resulting in some related stressors being considered in a single analysis.

- Basing analysis on residual risk, consisting of the impacts not addressed by current environmental management efforts.

- The analyses would not consider occupational exposure.

- The analyses would consider impacts in New Jersey, excluding impacts outside of New Jersey even if New Jersey sources may be the cause.

- The analyses would be divided into human health, ecological, and socioeconomic impacts.

- The impact criteria to be used in analysis.

The SC also directed the project coordination team to solicit direct public input by means of focus groups, questionnaires, public displays, and a newsletter. Public input helped to generate the list of environmental stressors evaluated by the project, and to guide the process of comparing disparate human health, ecological, and socioeconomic impacts due to these stressors.

The SC and TWGs interacted frequently, iteratively developing the scope, methods and expected work products of the TWGs. This was particularly true of the templates (see Appendix 2) defining the way impacts would be analyzed.

The project coordination team had the initial responsibility for guiding the SC in structuring the project. This included establishing a relevant scope for the project that would ensure that results could be used for DEP's coordinated planning functions.

Selecting and recruiting participants

Initial appointments to New Jersey's Steering Committee were made by then-DEP Commissioner Shinn. But because of the importance of the role of the Steering Committee, its membership was a continual focus. The credibility of the project required the Steering Committee to be perceived as a well-rounded group, not overly weighted with any single perspective. In order to ensure that this balance was achieved, the Steering Committee itself reviewed its membership and sought additional members when gaps in representation were noted. Some environmental groups were active throughout the process, but others withdrew after initial planning, for reasons of higher priorities for their time and/or disliking the idea of "yet another study" (see Appendix 1).

Technical working groups

Human Health, Ecological Quality, and Socioeconomic Technical Working Groups had the primary responsibility for developing impact assessments for dozens of environmental issues. The project coordination team selected chairs for the TWGs, and these chairs worked with the Steering Committee to identify individuals with expertise to contribute to the stressor analyses (Appendix 1).

The Steering Committee's charge to the TWGs was to assign a score to each stressor according to a set of criteria enabling a ranking of issues based on relative risks to human health, ecological quality, or socioeconomic well-being. The workplans for the Technical Working Groups were coordinated by the project team, which expanded to include each TWG's chair.

Public input mechanisms

There are two key reasons for ensuring that public input is incorporated into a comparative risk project. The first is to ensure that the project develops and reports information about the environment in a manner that reflects public values. The second reason is to build a broader audience for the communication of the results. Individuals who participate in the public input processes are more likely to pay attention to the completed report and future discussions that result.

Rutgers University students sought to determine the relative weight New Jersey citizens put on different kinds of environmental impacts. The results of this study showed that there was greater value placed on human health impacts than on impacts to ecosystems or socioeconomic factors, but the importance of ecological health and socioeconomic factors was still significant.

In a separate effort, project coordination staff held seven informal discussions with different groups to gauge their reactions to the scope of the project and the definition of issues and impact criteria. The focus groups included religious leaders, watershed associations, environmental commission members, and environmental justice and housing advocates. These meetings confirmed the Steering Committee's view that the range of environmental issues and impact types considered in this project should be broad.

As a result of these public involvement exercises, the overall structure of the project was kept broad in its scope and the reporting of relative risks was confirmed as important for future policy discussions.

Development of the issue list

An early challenge was to structure the analysis in a way that was both comprehensive and comprehensible, yielding analytic results of value to those deliberating environmental policy choices. Because of the need to answer the primary question in an analytically sound manner, the list of issues to be evaluated was a critical decision.

The choice of an appropriate structure for the problem list was informed by examples taken from many comparative risk projects that preceded New Jersey's. In most cases, projects developed a list of environmental problems based on existing regulatory programs or public concerns. Such an approach results in a list that is not only long (public input in Ohio led to a starting list of more than 700 issues), but complicated by overlapping topics. A list may include issues such as:

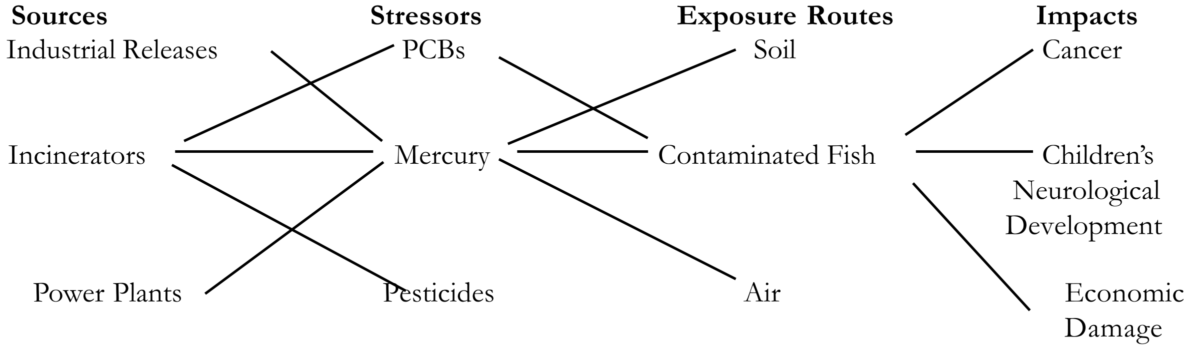
Contaminated fish
Solid waste incinerators
Mercury
Neurological impairment in children

All of these issues are important, but a systematic comparison of risks is difficult. Mercury is a pollutant that accumulates in contaminated fish, and solid waste incinerators are only one kind of source for mercury entering the environment. The impacts of mercury contamination may include neurological development effects in children. The web of cause and effect is complicated, and it is reasonable to ask whether this complexity can be overcome in a comparative analysis.

The example illustrates a connection between different kinds of environmental issues (Figure 1). In general, **sources** (solid waste incinerators) release **stressors** (mercury) that enter the environment and result in **exposures** (eating contaminated fish) that result in **impacts** (neurological impairment in children). Each of these kinds of issues requires a different analytic approach and reporting mechanism. An analysis of "contaminated fish" yields many types of stressors that create negative human health, ecological, and socioeconomic impacts. "Mercury" will be one of those stressors; PCBs and persistent pesticides are quite different in their paths of exposure and impacts. Similarly, an analysis of "developmental effects in children" will identify mercury as one of the stressors, with some exposures resulting from fish ingestion, some from other sources of mercury. The challenge for the comparative risk project was to provide information on all relevant issues without reporting a confusing mix of results from different analytical approaches.

The Steering Committee's solution was to strive for consistency by focusing the analysis on **stressors** (e.g. PCBs, pesticides, and mercury) while ensuring that a discussion of sources and exposures was included in each analysis and that impacts were reported in a consistent fashion to allow comparability. The

Figure 1. Relationships of Sources, Stressors, Exposure Routes and Impacts



Committee worked backward from "what matters most" in environmental quality (e.g., clean water) to be sure that important impacts and stressors were included.

The Steering Committee identified eleven broad categories of stressors. The TWGs detailed the stressors to include in these categories, amended in the light of reactions by the Steering Committee and attendees of the public focus groups. True comprehensiveness was an unattainable goal, but the final stressors list captured most of New Jersey's important environmental issues.

The complete list of stressors evaluated in this project is included on pages 100 and 101.

Issue analysis and criteria selection

After selecting the issue list, deciding the criteria against which to evaluate the issues was the next critical step. For the Human Health and Ecological Technical Working Groups, the result was a similar reporting template (Figure 2 and Appendix 2) which generally emphasized the following factors:

Figure 2. Content of Health Analysis Template
(see Appendix 2 for details on all three templates)

Hazard Identification

Stressor
Description of stressor (including etiology)
Stressor-specific impacts considered (including key impacts)

Exposure Assessment

Exposure routes and pathways considered
Population(s)/ecosystem(s) exposed statewide
Quantification of exposure levels statewide
Specific population(s) at increased risk
Quantification of exposure levels to population(s) at increased risk

Dose/Impact-Response Assessment

Quantitative dose/impact-assessment employed for each population considered

Risk Characterization

Risk estimate(s) by population at risk
Assessment of severity, persistence, irreversibility, frequency of effect(s)
Size of population(s) affected
Assessment of uncertainties in this assessment, data gaps
Potential for additional data to result in a significant future change in this risk estimate
Potential for future changes in the underlying risk from this stressor
Potential impact from catastrophic (low probability) events, likelihood
Extent to which risks are currently reduced through in-place regulations and controls

Relative Contributions of Sources to Risk

Impact Scores

- The magnitude of impact, often expressed as the frequency or probability that a stressor causes an impact of concern
- The geographic extent of exposure
- The severity of impacts
- Any special populations at risk
- The irreversibility of the problems caused by the stressor

Risk is calculated by considering both exposure and dose-response relationships. Exposure is the amount of a stressor that might be breathed or eaten or otherwise encountered by the general public, or by particular sub-populations that may be at greater risk, or by plants and animals. Dose-response relations map the different levels of impacts at different levels of exposure.

For each stressor, the TWGs detailed different levels of severity, effects, and irreversibility of effects to better describe the particular human health or ecological impacts of concern.

The Socioeconomic TWG used a somewhat different approach. The first decision for the group, in consultation with the Steering Committee, was the determination of what specifically to include in an analysis of socioeconomic risk. Numerous comparative risk projects around the country have developed socioeconomic analyses of environmental issues (sometimes called "Quality of Life"). The TWG and Steering Committee reviewed these and selected the following five categories:

- Property values
- Employment
- Costs (medical, physical damage, etc.)
- Aesthetic damage
- Psychological damage

Compared to human health and ecological impacts, there are fewer research results available on the socioeconomic impacts of environmental stressors. Therefore, the TWG used many sources of information regarding these types of impacts and attributed them to individual stressors with varying degrees of uncertainty (e.g., using property values impacts of brownfields to estimate such impacts for stressors often found at contaminated sites).

Deliberations of the Steering Committee resulted in the incorporation of additional factors in the assessments. They directed the TWGs to include the likelihood of catastrophic events, because their impacts can be important to consider even if the likelihood is very low. The Steering Committee also directed the TWGs to describe any trends in their analyses to capture any significant differences between current and future risks. Finally, the TWGs documented the degree of confidence in each risk assessment. Characterizing uncertainty was an important step in assigning different levels of risks, as well as providing directions for research (see pages 59-60 on uncertainty).

Each human health, ecological, and socioeconomic analysis also includes:

- A description of the stressor
- A list of the sources of the stressor
- A brief summary of the current strategies to control the risk
- The potential for additional data (if it were to be collected) to alter the risk estimate
- A list of specific subpopulations, species, or ecosystems at greater risk
- Ranking of the impacts posed by the stressor.

This report provides summaries of the information that led to the rankings. More detailed information is available in Appendices 3-5.

Human Health Impacts

How were human health risks evaluated?

The general approach for ranking human health risks considers three factors:

- Severity of the risk
- Size of the population affected

Any special populations at risk.

How were the scores used in the ranking determined?

The scores that were used to produce the human health risk ranking were derived from the relative severity of each health effect, the relative size of the population at significant risk, and whether there were discrete communities at elevated risk. Ranks were initially assigned by the authors using a common template, and then reviewed by the TWG Chair for completeness, accuracy, consistency, and reasonableness. The ranking was then reviewed independently by two reviewers. If the two reviewers agreed with the overall ranking assigned by the author to within one grade (i.e., H, M-H, M, M-L, L), the author's ranking was retained. In the few cases where the reviewers and authors failed to agree to within one grade, the TWG Chair mediated a discussion between the author and reviewers to facilitate a compromise. The full set of rankings was then reviewed by the full TWG for consistency and reasonableness. As with other TWG products, the final ranking of issues is subject to data gaps, uncertainty and the possibility of alternative application of subjective factors.

Severity

The severity of a stressor addresses both the type of adverse effect (e.g., cancer, skin irritation, developmental effects), and the magnitude of the risk for each effect at the exposure levels currently encountered in New Jersey. For example, while cancer is generally a severe endpoint, the risk of a cancer occurring to someone in New Jersey as a result of that person's exposure to a stressor may be low because exposure levels are low. For many of the stressors, cancer is an endpoint of concern, and in many cases, cancer leads to premature death. As a result of this factor, there is significant focus on cancer endpoints in the analysis. However, other stressors which act during fetal development can result in permanent effects on function and performance (including intelligence). No systematic distinction between the severity of different health effects was attempted in the human health assessments.

In addition to the severity of the outcome, the potency of the stressor was also considered. Thus, a carcinogen with relatively low potency (i.e., a large dose is needed to yield a given impact) might not, other factors being equal, be considered to be as severe as a carcinogen or a developmental toxicant that needs a smaller dose to produce the same effect (high potency).

Size of population

The size of the population exposed is a critical factor in the assessment of the overall population-based risk. If few people are exposed to a potent toxicant, few adverse effects will occur in the population as a whole. The magnitude of the exposure was a primary determinant of risk. All other factors being equal, the larger the exposure, the greater the risk. The frequency and duration of exposures is also a critical factor. For most stressors, brief and/or intermittent exposures even to a large population will carry less risk than more prolonged or frequent exposure (not necessarily true for pathogens). Some are more localized in their route of exposure (such as asbestos, radon), leading to a lower number of individuals affected. Stressors that are airborne (ozone) or present in drinking water (disinfection by-products) and foods (mercury, PCBs) may affect a large portion of the state's population.

Specific populations

The stressor analyses include information about specific populations at risk. Some populations are exposed to greater levels of a stressor and some populations are more susceptible to disease from exposure. An example of the former is dioxin exposure in populations whose diets contain unusually high proportions of fish or shellfish caught in contaminated waters. An example of the latter is lead exposure. Children, due to their rapidly developing neurological systems, are more susceptible to the effects of lead contamination than adults.

Ecological Quality Impacts

How were ecological risks evaluated?

The general approach developed by the Ecological Quality Technical Working Group was to consider three factors: the *severity/ irreversibility* of the effects(how bad are they when they happen?), the *frequency* of effects(how often do they happen?), and the *magnitude* or geographic extent of the effects (how much of New Jersey do they affect?).

How were the scores used in the ranking determined?

The scores that were used to produce the ecological risk ranking were derived from the relative severity, frequency, and magnitude of the stressors' effects as judged by members of the Ecological Quality Technical Working Group. Analysts used a common template (see Appendix 2) for evaluating data relevant to each stressor, and used the information to generate scores.

To account for these variations across ecosystem types, the ecological TWG identified five major ecosystem types for evaluation:

- Inland waters
- Marine waters
- Wetlands (freshwater and tidal)
- Forests
- Grasslands

For example, adverse effects from a stressor may occur predominately in marine waters, or it may not occur in marine waters at all. The TWG scored each ecosystem type 1 to 5 on each of the three criteria, multiplying the factors to achieve a single score (range 1 to 128) for each ecosystem type (see Figure 3). The TWG could not justify providing more weight to any single ecosystem type, therefore the resulting five scores were averaged to arrive at a single stressor score for the state. These scores were then used as the basis for the ecological risk ranking.

A result of this scoring scheme is that there are notable differences among issues that share similar rankings. Some issues ranked highly because of more moderate impacts across all ecosystems, or because of large impacts on a few ecosystems.

Severity/Irreversibility

The relative severity of a given ecological impact lies somewhere along a continuum of effects ranging from no detectable effect to a permanent, fundamental alteration or loss of an ecosystem. Severity may be expressed in terms of the seriousness of health/population effects in affected species: decreased reproductive success is a less severe effect than acute toxicity or death. It may also be expressed as a function of reversibility. The physical removal of habitat is judged to be more severe than a biological or chemical impact to habitat, from which the ecosystem may recover.

For many chemical stressors, the severity and irreversibility factors were considered using standard risk assessment methods. The assumption is that as exposure increases to a particular chemical, animal and plant species will experience increasingly severe health/ population effects. For many chemicals,

Figure 3. Ecosystem Assessment Scoring System

	Inland Waters	Marine Waters	Wetlands	Forests	Grasslands
Severity					
Frequency					
Magnitude					
Total Score (SxFxM)					

Average Total Score: _____

reference exposures have been developed and accepted by ecotoxicologists as the thresholds for adverse effects in wildlife. The actual concentrations observed in New Jersey can be compared with these threshold values to produce a Hazard Quotient. The greater the chemical concentration, the greater the exposure, and consequently the hazard quotient value. The resulting hazard quotients help determine the severity factor for these chemical stressors.

For biological and physical stressors, analysts typically considered the numbers of species affected by the stressor, the ways they are affected, and the resulting impact on the structure and functioning of the ecosystem. Thus, a stressor that affects a "keystone" species or species at the base of the food chain may precipitate ecosystem-wide changes, and will be judged higher on the severity factor than a stressor that affects a species with fewer ecosystem ramifications. Again, the potential for reversibility of the impacts will also determine the degree of severity for physical and biological stressors.

Frequency

Frequency refers to the rate at which adverse effects are occurring or are predicted to occur. At the low end of the scale, there may be little or no chance that the stressor will ever create impacts in New Jersey. The stressor may cause problems on a rare or occasional basis, or, at the high end of the scale, is often and increasingly present in New Jersey.

Magnitude

In evaluating ecological risks, magnitude refers to the extent of the stressor's impact (percent of the state affected) across species, habitats or populations. This factor was used to allow comparison of the scale of impacts on a statewide basis. For some stressors, magnitude was also described in terms of the proportion of target species affected—percent of hemlock trees, number of species of birds.

Socioeconomic Impacts

Overall Process

Procedures for estimating the socioeconomic impacts of environmental stressors are in their infancy, and relevant data are even scarcer and more uncertain than equivalent data for human health or ecological impacts. As a result, most comparative risk projects have limited themselves to qualitative description of potential "quality of life" impacts. The members of the Socioeconomic Technical Working Group (SETWG)—representatives of several state government agencies, academia, EPA-Region II, and Resources for the Future, a nonprofit "think tank"—felt that, despite the difficulties, they would be abrogating their responsibilities if they limited themselves to description. They decided to set up, by consensus, criteria for (1) kinds of impacts that would be covered, (2) thresholds—such as minimum dollar amounts for economic impacts—for awarding Severity scores of High, Medium or Low, and (3) equivalent scores for assessing Duration and Scale (see below for definitions). The hope was that this approach would help analysts by allowing them, in the absence of stressor-specific information, to judge whether it was plausible for that stressor to exceed a given threshold in impacts. TWG members also thought it would help audiences by making the analytic process more transparent, and assuring that any error in such judgments was likely to occur in the same way for other stressors, thus making judgments of <u>relative</u> impacts more likely to be accurate. Once the SETWG agreed on these criteria, graduate students overseen by the TWG co-chairs (plus a few TWG members) applied these criteria to particular stressors. Completed analyses were reviewed by TWG co-chairs and by external reviewers from academia and EPA.

In general, SETWG did an analysis of socioeconomic impacts for all stressors addressed by either the Human Health or Ecological

Quality TWGs, although in some cases (e.g., invasive plants) it combined stressors analyzed individually by another TWG.

Criteria

After considerable discussion, the SETWG settled upon five classes of socioeconomic impact that seemed to be important to people, while allowing reasonable justification (via evidence or logical argument) for judgments of impact. Many other kinds of impact were discussed, but they were deemed either less important or (usually) without any plausible or systematic basis other than personal opinion to support impact decisions.

Property Values. These values can decline in the presence, or suspected presence, of an environmental hazard. Concerns about property value impacts have been raised by citizens for local hazardous waste sites, proposed new nuclear power or waste disposal facilities in the area, or publicity about one's home being tested for indoor radon levels. The limited literature on this topic has concentrated on the effect of waste sites or industrial facilities of various kinds, and almost none of it has concerned the impact of stressors as defined in this study. This posed problems for analysis—for example, for many chemical stressors impacts on property values were extrapolated from waste-site values, which often contain such chemicals—but this class of impact was deemed important enough to risk such uncertainty in judgment.

Employment. This was another economic impact that seemed important to people and worth including. Although stressor-specific data were scarce here as well, potentially affected economic sectors were often obvious enough (such as fisheries or tourism) to make plausible judgments of the relative size of the impact. Multiplier effects (that is, one lost job in fisheries, for example, might result in additional lost jobs indirectly, through the fisherman's reduced expenditures on groceries, movies, etc.) were not estimated, since data on the magnitude of such effects for environmental stressors were unavailable.

Costs. Environmental problems cause out-of-pocket expenses, including health-related costs (such as hospital and other medical costs, lost wages), property-related costs (such as damage to automobiles, equipment, buildings, and infrastructure), production-related costs (such as damage to crops or fisheries, lost production of goods and services), and residual damages not otherwise accounted for. Because the focus of the NJCRP was on direct impacts of environmental stressors, not on management options, the costs of cleaning up the environment (for example) were not included in these estimates. The socioeconomic literature, combined with estimates from the other TWGs of the magnitude of human health or ecological impacts, allowed some plausible judgments of the magnitude of costs incurred.

Aesthetics. Environmental stressors, directly or indirectly, can offend human eyes, ears, or nose with obscured or unsightly views, awful noises, and bad smells. Evidence that people's environmental concerns are often driven by the experience of smarting eyes or noxious odors, as much or more in many cases than by abstract concern over health impacts, suggested that this was an important category of impacts to include. Clearly judgments of the magnitude of such aesthetic insults can vary, but equally clearly the literature and the other TWGs' evidence (such as that a given chemical stressor cannot be seen, tasted or smelled) allow some plausible judgments about relative impact.

Psychological Well-Being. Considerable debate occurred over this class of impact. Some TWG members argued initially that in analyses that were supposed to provide scientific judgment of the relative impact of stressors, it was imprudent to include an impact that seemed to reflect largely public, non-scientific beliefs. However, consensus was eventually reached that "worry" was a real social impact, whether it was transitory anxiety or full post-traumatic stress disorder, and deserved inclusion. Worry was defined as an emotional response to the combination of a perceived threat and perceived inability to control that threat, the one measure of psychological well-being on which there was some scientific literature. Furthermore, property value impacts were largely due to the perceptions of home buyers, realtors, and insurers about potential or actual environmental impacts: why should those perceptions be treated as any more "real" than worry simply because they were being estimated in dollars? As with property value impacts, considerable extrapolation from the limited data available was necessary, so results should be treated with caution. However, the systematic approach taken by the SETWG allows readers to judge for themselves the accuracy of these judgments. The inclusion of both property value and psychological impacts allowed "triangulation," with convergent results from different methods increasing confidence that the "true" relative value of socioeconomic impacts had been identified.

Criteria Definitions and Thresholds

Severity Criteria. Criteria were set to allow analysts to consistently determine the Severity of each class of impact for a given stressor, from 3 (High) to 1 (Low). For the first two economic-impact classes, the declines in property values and employment associated with the last severe recession in New Jersey (1988-1992) were used as the benchmark for High impacts, on the grounds that this would be a plausible analogy for most readers.

Property values in New Jersey dropped 4.2% from 1990 to 1992, the low point of the 1988-1992 recession. Thus 4.2% of all property values in New Jersey (over $442 billion) in 1998, or $21.8 billion, was set as the threshold for High impacts. A tenth of that (0.42%), or $2.18 billion, was the threshold for Medium impacts; anything less than that was presumed to be Low impact.

The 1988-1992 recession reduced employment by 5% in New Jersey. This value, or 200,000 jobs in 1997 (based on NJ Department of Labor data), was the criterion for High job impacts. A tenth of that (0.5%), or 20,000 jobs, was deemed a Medium impact, with anything less being deemed a Low impact.

A "high" (3) cost impact was defined as annual costs greater than $160 million statewide, roughly equivalent to a cost of $20 per person per year in New Jersey. The breakpoint for a "moderate" impact rating is defined as any stressor creating costs between $16 million and $160 million. Stressors creating costs of less than $16 million were assigned "low" scores.

Aesthetic severity was a combined judgment of levels of annoyance and presumed ability to avoid or adapt to the aesthetic insult. High Severity was deemed to occur when the impact was strongly annoying and avoidance or adaptation would be relatively costly or inconvenient, such as living under the flight path of an airport. Medium Severity involved moderate annoyance with moderate inconvenience or cost to avoid or adapt, or strongly annoying offenses that can be avoided or adapted to with little inconvenience or cost. Low ratings were assigned when little or no offense to the senses was likely, or moderate annoyance could be easily avoided or tolerated, such as purchasing a water filter to improve the taste of tap water.

Analysts were asked to take the role of an "average" resident of New Jersey in estimating the severity of worry about actual or potential impacts of a stressor on that person's immediate family and community. High Severity was judged to occur when the stressor is familiar or easily sensed, and arouses great worry. Medium scores were assigned when a familiar stressor seemed likely to arouse only moderate worry, or was unfamiliar but its impacts (if known) might arouse great worry. Low Severity scores were awarded to stressors that seemed to be familiar and unworrying, or unfamiliar but seemed unlikely to arouse much worry if their impacts became known.

Duration and Scale Criteria. Duration refers to the length of time that impacts are likely to persist: some are of short duration or reversible (e.g., unemployment in most cases), others can last for much longer and even be permanent. For example, a Duration score of 3 was assigned to unemployment that would seem to last more than the five-year time horizon of the NJCRP; a score of 2 if the job loss might last 1-5 years; and a 1 if it seemed to last less than a year. Scale encompasses the proportion of the state's area or the state's population affected. A Scale score of 3 was applied to statewide impacts, of 2 if impacts affected numerous neighborhoods, more than one county, or a subpopulation of more than 1000 people, and of 1 if impacts were highly localized, affecting only a few neighborhoods, a single county, or a small subpopulation.

How were the scores used in the ranking determined?

Each stressor was evaluated on five impact categories (property values, employment, costs, aesthetics, psychological well-being), and for each impact type a 3, 2 or 1 score was assigned separately for the Severity, Duration and Impact of that impact. For each impact type, its severity, duration and impact scores were multiplied to get a sub-score for that impact type (e.g., Unemployment=6 if Severity=3, Duration=2, and Scale=1). Then the sub-scores were averaged across the five impact types to get the overall score (Figure 4). Peer reviews were conducted by the TWG chair and outside reviewers.

In addition to this overall score, analysts also estimated the average uncertainty in that score, on the grounds that it would be useful for readers to know the degree of confidence analysts had in the score (Figure 5). This was based on the following criteria:

- High Uncertainty (3) was defined as cases for which the impact estimate was qualitative and poorly documented, no scientific consensus exists for estimating impacts, and/or no data specific to New Jersey were available. Scores were, on balance, quite arbitrary, and could be off by more than one (High vs. Low). It was no more probable that the reported score was correct than that a lower or higher score was correct, so the probability that the reported score is correct was about 33%.
- Medium Uncertainty (2) scores were assigned when some documentation existed, a literature relying on this estimating approach existed, and/or some New Jersey-specific data were used. If scores were wrong, they were, on balance, only off by one (such as High vs. Medium). There was at least a 50% probability (even odds or better) that the reported score was correct.
- Low Uncertainty (1) meant that the impact estimate was quantitative and well documented, scientific consensus existed on the estimation method, and/or New Jersey-specific data were used. It was highly probable (67% or better, for example one standard deviation) that the reported score was correct.

Figure 4. Socioeconomic Assessment Scoring System

Socioeconomic Impact Evaluation of Environmental Issue:
Scoring system: High (3), Medium (2), Low (1), and Insignificant (0.1).
Subtotal Risk = multiplicative product of the three factors; Total Risk is the sum of subtotal risks.

Socioeconomic Impact **Factors Affecting Risk Estimation**	Property Values	Employment	Costs Incurred	Aesthetic Levels	Psychological Impacts
Severity					
Duration/ Irreversibility					
Scale (spatial, population)					
Subtotal Risk					

Average Risk (0 – 5 years)	Average Risk (5 years plus)

Figure 5. Socioeconomic Uncertainty Scoring System

Socioeconomic	Property Values	Employment	Costs Incurred	Aesthetic Levels	Psychological Impacts	Average Uncertainty
Uncertainty Level						

ANALYSES - Process

Examples of Analytic Results

The assessment of relative impacts of environmental stressors on human health, ecological quality, and socioeconomic conditions has been the focus of the analysis so far. In addition to the stressor-specific impact summaries and analyses, these rankings may be the main interest for most readers of this report.

However, the full analyses contain much more information than these overall rankings. Just as the Steering Committee decided to forego a single ranking integrating health, ecological and socioeconomic impacts, on the grounds that such a ranking would obscure important information, the same could be said of the three overall rankings-each provides only one of several perspectives on environmental impacts. The purpose of this section is to provide alternative perspectives based on the full set of information, which may prove equally valuable to audiences for this report. Details on each of these dimensions of environmental impact can be found in the full analysis for each stressor (Appendices 3-5).

Some of this information involves further details, and implied rankings, based upon information that appears in the earlier ranking tables. **Uncertainty** can be a critical factor in how one evaluates overall rankings: for example, one might be more confident that major action is warranted on a high-ranking stressor with low uncertainty than on a high-ranking stressor with high uncertainty. Uncertainty also can be important in setting priorities for environmental monitoring, data analysis, and research, since these activities can help increase confidence in impact estimates or stressor reduction strategies. This section thus includes a ranking of stressors by level of uncertainty, plus a set of monitoring, analysis, and research priorities proposed by the Technical Working Group (TWG) chairs.

Analysts were asked to project the **Trend** of impacts (getting better or worse, or staying the same) in the immediate future, on the grounds that knowing which stressors were likely to worsen their impacts might be as valuable in priority-setting as knowing their current impacts. They were asked to judge how trends in the recent past might be affected by likely near-term policy or other changes (excluding the effect of hypothetical changes of which there was no plausible evidence). The short-term trend analysis was intended to minimize the errors that accumulate at an ever-increasing rate as predictions are made further into the future. This short-term focus may have understated the trend for a few stressors (such as greenhouse gases), but otherwise allows comparability. Stressors are grouped by whether the judged trend is better, the same, or worse.

Catastrophic potential is the likelihood of a major disaster occurring as the result of a single incident or closely-grouped (in time) set of incidents. Substantial impacts can occur, but these may be very unlikely (low probability of occurrence). Although relatively few stressors were judged to have more than “low” catastrophic potential, this was assessed by analysts and ranked in this section in case it would be useful to readers.

This section also offers information on **“populations at risk.”** The overall rankings are based upon estimates of statewide impact, but in many cases there are human sub-populations, ecosystems, non-human species, or geographic locations within New Jersey that are at particular risk. This can be important for priority-setting: for example, it might be deemed important to deal with stressors that put fetuses and children at particular risk even if those stressors are ranked low in overall impact. Information on these at-risk sub-populations, ecosystems, species and locations is provided for each TWG, as appropriate.

The Socioeconomic TWG analyzed impacts for **five different conditions** before producing an overall impact score. Since some people might find some of these conditions more important than others, this section provides rankings for each of the five dimensions separately.

TWGs also were asked to identify major **sources of stressors**, such as large business or agriculture, as a potential first step in identifying risk-reduction strategies. These sources are identified for the Health and Ecological TWGs.

Finally, earlier sections of this report summarized findings on the basis of category of impact: human health, ecological quality, and socioeconomic conditions. Some people might be more comfortable with discussions of impact according to the **type of stressor**, of which many such categorizations are possible. Here impacts are summarized according to whether stressors are biological (such as a plant or animal or microorganism), chemical (the kind of environmental stressor with which most people might be most familiar), or physical (such as light, noise, or radiation).

Uncertainty

In any scientific endeavor, some uncertainty is inevitable. Uncertainty arises from incomplete or conflicting information, such as whether a stressor causes cancer in humans, how large an area is affected by a stressor, or whether a given concentration of a stressor in streams harms aquatic species. There may be good understanding about environmental impacts in general, but not about a stressor's occurrence, exposures to it, or vulnerable populations in New Jersey. In such cases, data from other sources may be extrapolated to New Jersey, which might over- or underestimate the impacts in this state.

Uncertainty itself may in some cases become a stressor, when it heightens worry about a particular stressor, potentially affecting such outcomes as property values. Once the nature and extent of a hazard are well-established, people and institutions usually find ways to cope with it; if its existence or magnitude are uncertain, this interferes with everything from investment decisions to choices of where to live.

TWG analysts were asked to report their level of confidence in the impact estimates they produced, on a scale from "high" to "low" uncertainty. The examples in the following table show the varied confidence in rankings even for high-ranking stressors. For example, health impacts from lead and radon, and ecological impacts from land use change, are viewed as quite certain by analysts, but health impacts of indoor microbes and ecological impacts of historical use of pesticides are quite uncertain. Sometimes different TWGs analyzing the same stressor came to identical conclusions about the uncertainty, but in other cases—due to differences in the impacts considered or available evidence—they did not.

Information about uncertainty in rankings, both that given in the following table and the more detailed information in the full analyses (Appendices 3-5), can help decision-makers determine what kinds of additional information might be most useful in setting priorities for reduction of environmental impacts. (Recommendations by TWG chairs on research, data assessment, and monitoring priorities appear after the Uncertainty table.)

One caution should be noted. When there is relatively high uncertainty, this can pose difficulty for ranking stressors. Should one provide a "high" rank, so as to err on the side of caution? A "low" rank, given the absence of firm evidence of any harm? A "medium" rank, to hedge one's bets? Or refuse to rank the stressor at all because of the high uncertainty? Comparative risk projects have taken at least one of these options, and often all of them across various stressors; none is more or less valid. In the New Jersey project, TWGs did not establish standard approaches to this problem (except for avoiding non-ranking), so judgments for particular stressors may not be entirely consistent. However, given that the aim was relative rather than absolute rankings, and that the number of high-ranked stressors with high uncertainty is relatively small, this is unlikely to skew the results greatly.

Table 6. Rankings of Stressors by Level of Uncertainty
Overall Ranking

UNCERTAINTY	RANKINGS: High/Medium-High	RANKINGS: Medium
High	Indoor asthma inducers (H) Land use change (S) Lead (S) Pesticides-historical use (E) Pesticides-indoor (H)	Chromium (H) Endocrine disruptors (H) Indoor microbial air pollution (S) Legionella (H) Mercury (H) Pesticides-food, outdoor, water (H) Phthalates (E)
Medium-High	Arsenic (S) Deer (S) Indoor asthma inducers (S) Particulate matter (S) PCBs (S) Pesticides (S) Petroleum spills (S) Phosphorus (S) Radium (H) Secondhand tobacco smoke (S) Ultraviolet radiation (S)	1, 3-butadiene (H) Acrolein (H) Endocrine disruptors (S)
Medium	Carbon monoxide-indoor (H) Dioxins/furans (H) Habitat loss (E) Mercury (E) Ozone (ground level) (H) Particulate matter (H) Polychlorinated biphenyls (PCBs) (H, S) Secondhand tobacco smoke (H) Ultraviolet radiation (E) Volatile organic compounds-carcinogenic (H)	Arsenic (H) Benzene (H) Cadmium (E) Dioxins/furans (S) Disinfection byproducts (H) Endocrine disruptors (E) Formaldehyde (H) Geese (E) Inadvertent animal mortality (E, S) Invasive plants (E, S) Lead (E) Nitrogen pollution (E) Noise (S) Overharvesting (marine) (E) Ozone (ground level) (S) PAHs (S) Petroleum spills (E) Polychlorinated biphenyls (PCBs) (E) Radon (S) Starlings (E) Sulfur oxides (S) Water overuse (S)
Medium-Low		Deer (E) Nitrogen oxides (H)
Low	Habitat fragmentation (E) Increase in impervious surface (E) Lead (H) Radon (H) Hemlock woolly adelgid (E)	Catastrophic radioactive release (E) Phosphorus (E) Ultraviolet radiation (H)

Stressors with Low Overall Ranking and High/Medium-High Uncertainty:

Health:
- Cryptosporidium-drinking water
- ELF/EMF
- Greenhouse gases
- Indoor microbial air pollution
- MTBE
- Noise
- PAHs
- Waterborne pathogens-drinking water (M-H)
- West Nile virus (M-H)

Ecological:
- ELF/EMF (M-H)
- Genetically modified organisms
- Light pollution
- Off road vehicles
- Pets as predators
- QPX parasite in shellfish
- Road salt

H=Health TWG, E=Ecological TWG, S=Socioeconomic TWG

Monitoring, Data Analysis and Research Needs

The uncertainties and data gaps discussed briefly here, and in more detail in the individual stressor analyses (see Appendices), offer opportunities for environmental monitoring, analysis of existing data, and/or research to reduce uncertainties about impact rankings or to help identify strategies for impact reduction. The following are suggestions for monitoring, analysis, and research for stressors whose relatively high overall rank and/or uncertainty imply these priorities will be particularly helpful, offered by the chairs of the Human Health and Ecological Quality Technical Working Groups. Generic suggestions for improving Socioeconomic Conditions impact estimates follow.

HUMAN HEALTH

Stressor (Overall Rank, Uncertainty)	**Needs**
Dioxins/Furans (H, M)	**Monitoring** The extent of exposure to dioxins in the New Jersey population is not known. While there is a significant background level of exposure in the U.S. in general from the diet, environmental contamination data suggest that some populations may have exposures which are significantly elevated above background. These include consumers of contaminated crabs in the New York/New Jersey Harbor Estuary. **Research** Very limited data exist on the health effects of dioxin, particularly its developmental effects (of increasing concern), and the human-specific dose-response relationships for those effects.
PCBs (H, M)	**Research** Different mixtures of PCBs are present in the environment, and in human tissues. The relative risk of different types of health effect (e.g., cancer, developmental deficits) for the different individual PCBs and their numerous mixtures is not clearly understood.
Ozone, ground level (H, M)	**Research** Some data reveal the relationship between ozone levels and severe cases (hospital and emergency room emissions) of asthma in New Jersey, but the extent to which milder cases of asthma are related to ozone levels in New Jersey is not known. Further research is needed to assess the health impact of current ozone levels in New Jersey.
Indoor asthma inducers (M-H, H)	**Research** Although some of the triggers of asthma in the indoor environment are known, the overall etiology of asthma and the environmental contribution are not yet well understood. The combination of environmental triggers is complex and their interaction is not understood. In addition, the interaction between indoor and outdoor triggers (e.g., ozone) is not understood. Epidemiologic studies are needed to elucidate these contributions and interactions, and their possible relationship to the causation of asthma.

HUMAN HEALTH

Stressor (Overall Rank, Uncertainty)	**Needs**
Radium (M-H, M-H)	**Monitoring** Because water softeners remove radium to some extent from tap water (whether used for that purpose or for general removal of minerals in hard water), the extent of increased radium exposure at the tap in New Jersey is not known. In addition, radium exposure through ingestion of New Jersey dairy and agricultural products is not known.
Volatile organic chemicals (VOCs) – carcinogenic (M-H, M)	**Research** The prime uncertainty is carcinogenic potential for humans at environmental levels of exposure (currently extrapolated from animal models), which may be reduced by basic research into the toxicology of these compounds.
Chromium (M, H)	**Monitoring** Few measurements of chromium concentrations in air are available. Model-based predictions are highly uncertain as to the fraction of total chromium contributed by the carcinogenic hexavalent form. The prevalence of chromium allergic sensitivity in the population is not well characterized, and there are few if any data on the incidence of chromium allergic dermatitis from non-occupational exposures. **Research** Current data do not suggest hexavalent chromium is carcinogenic by ingestion, but few studies directly address the potential health impact of this route of exposure.
Endocrine disruptors (M, H)	**Monitoring** There are no data on human exposure to potential endocrine-disrupting chemicals in the New Jersey environment. For many endocrine disruptors, exposure is likely to have both dietary and environmental components which may be difficult to separate. Exposure surveys and ultimately monitoring of the New Jersey population are needed to address these considerations. **Research** Endocrine-disrupting potential is known for few environmental contaminants; only a small fraction of chemicals of potential concern have been screened or tested, and reliable short-term screens for endocrine disrupting activity are still under development. The relationship between animal models or in vitro testing and demonstrable effects in humans is not clear.
Legionella (M, H)	**Monitoring** Because legionella is not accurately diagnosed or reported in most cases, the estimates of its incidence and its mortality in New Jersey are highly uncertain. The number of deaths per year in New Jersey estimated to result from legionella infection varies six-fold as a result.

HUMAN HEALTH

Stressor (Overall Rank, Uncertainty)	**Needs**
Mercury (M, H)	**Monitoring** Data on exposure to elemental mercury are lacking entirely for its use in cultural/folk practices or due to spills and breakage in homes. Few or no data are available on the extent of exposure to methylmercury in New Jersey among high-end fish consumers. **Research** Few studies of good quality are available on the risk of relatively subtle and/or idiopathic health effects from low-level elemental mercury exposure from dental amalgams. Few data are available to characterize potentially subtle health effects from exposure to methylmercury among adults and older children.
Pesticides-indoor (M, H)	**Monitoring** There are few or no data on indoor pesticide use or exposure in New Jersey. Systematic monitoring could document the extent of exposure and risk to various populations in New Jersey. **Research** The sensitive populations for various pesticides are not clearly defined. In addition, the effects of low or moderate exposure to pesticides on sensitive populations are not well characterized.
Pesticides-outdoor (M, H)	**Monitoring** There are few or no data on outdoor pesticide use or exposure in New Jersey. Systematic monitoring could document the extent of exposure and risk to various populations in New Jersey. **Research** The sensitive populations for various pesticides are not clearly defined. In addition, the effects of low or moderate exposure to pesticides on sensitive populations are not well characterized.
Pesticides-water (M, H)	**Monitoring** Few data exist on pesticide levels in private wells. **Research** Although levels in public-supply drinking water are uniformly low, little research has been done on possible interactions of low levels of multiple pesticides (also a concern for private wells).
Acrolein (M, M-H)	**Monitoring** Few data are available on indoor levels of acrolein. **Research** EPA's Reference Concentration for acrolein, the basis for estimates of potential impacts at concentrations measured or modeled in New Jersey, stems from animal data with a relatively large uncertainty factor adjustment (1000).
1,3-butadiene (M, M-H)	**Monitoring** Measurement data (as opposed to model predictions) of New Jersey concentrations exist only for the Camden area. Risk estimates for other areas, and for the state as a whole, are based solely on modeled data. Increased air monitoring is needed to validate the model-based predictions. **Research** Generic uncertainty exists on extrapolation of human cancer risks from animal toxicity data, and human epidemiologic data on cancer risk are somewhat contradictory.

HUMAN HEALTH

Stressor (Overall Rank, Uncertainty)	**Needs**
Arsenic (M, M)	**Research** Fundamental uncertainties exist about the basic toxicology of arsenic, including the shape of the cancer dose-response curve at low doses. Current measures of arsenic exposure are potentially confounded by the much less toxic (organic) forms of arsenic ingested with seafood.
Benzene (M, M)	**Monitoring** There are few data on benzene levels in private wells in New Jersey. Data on exposure to benzene in air are limited to model predictions. **Research** Although the cancer potency data for benzene are based on human occupational studies, significant uncertainty exists in the interpretation of those data for derivation of cancer potency estimates.
Disinfection byproducts (M, M)	**Monitoring** There is no systematic monitoring of drinking water in New Jersey for disinfection byproducts other than trihalomethanes. **Research** The various possible disinfection byproducts can occur with various frequencies, in various combinations, and at various concentrations. This makes interpretation and application of epidemiologic data uncertain.

ECOLOGICAL QUALITY

Stressor (Overall Rank, Uncertainty)	**Needs**
Habitat loss (H, M)	**Monitoring** There is a great need for ongoing quantitative analysis of loss of different kinds of habitat at the state level to determine if rates of land use change are increasing, decreasing or stable. **Research** There needs to be more research that focuses directly on the effects of habitat loss on New Jersey plants and animals.
Pesticides-historical use(M-H, H)	**Monitoring** More monitoring needs to be done to see how many of the bodies of water in New Jersey have chlorinated pesticides found in the sediment, water column, and aquatic life. Also more monitoring needs to be done to see how many more contaminants are entering New Jersey's surface and ground water due to erosion and runoff of soil from the urbanization of farmland. Migrating birds such as ducks and geese should be monitored for DDT and other pesticides by analyzing the wings of hunter-killed waterfowl. **Research** More research is needed to see if levels of DDT, chlordane, and other chlorinated pesticides and their metabolites found in New Jersey's environment are acting as endocrine disrupters on at-risk species in New Jersey. Other potential effects of chlorinated pesticides that should be investigated include immune suppression and abnormal nesting behavior (adversely affecting chick survival) in New Jersey gulls and terns.

ECOLOGICAL QUALITY

Stressor (Overall Rank, Uncertainty)	Needs
Metals (mercury, cadmium, lead) (M-H or M, M)	**Monitoring** There are limited data for most metals including those ranked M or M-H for all media (e.g., soil, sediment, and surface water), and limited temporal/spatial data. No or limited (e.g., mercury) monitoring of biota. **Research** Effects of metals-contaminated sediment on benthic organisms. **Data Analysis** Increased use of electronic data/data storage will allow more in-depth analysis of spatial/temporal patterns of metals in media (e.g., soils, sediments) and allow comparison with ecological benchmarks.
Endocrine Disruptors (M, M)	**Monitoring** Additional chemical concentration data are required to better characterize both the severity and extent of endocrine disruptors. Systematic periodic monitoring data are necessary to properly assess whether endocrine disruptor contamination or exposure is improving or degrading. **Research** Data on effects are needed. There are a large number of untested compounds.
Natural Resource Use and Impacts (Overharvesting (marine) , Water Overuse, Inadvertent Animal Mortality) (M, M)	**Monitoring** The magnitude of overharvesting of horseshoe crabs in New Jersey needs to be determined. There is a lack of comprehensive data on inadvertent animal mortality. **Research** Water overuse: need to develop ecological flow goals and methods; a USGS-DEP research project is underway to examine the flow characteristics and basis for developing ecological flow goals and methodologies for New Jersey streams. Data from this project may help define the current risk and impacts of water overuse in the state.
Nitrogen Pollution (M, M)	**Research** Fuller understanding of the nitrogen cycle could shift the concern from local water quality to regional water quality, terrestrial ecosystems, and the global climate.
PCBs (M, M)	**Research** Research that isolates PCB-specific impacts from impacts due to general chemical pollution is needed. **Data Analysis** Increased use of electronic data will allow more in-depth analysis of spatial/temporal patterns of PCBs and other organic compounds in media (e.g., soils, sediments) and allow comparison with ecological benchmarks.
Petroleum Spills (M, M)	**Research** Effects of repeated small oil spills on ecosystems.
Plants, Invasive (M, M)	**Monitoring** Statewide populations/occurrences, and rates of spread; long-term monitoring of control efforts are needed. **Research** Quantification of impacts is needed (e.g., biodiversity impacts). Comprehensive research plan is recommended.
Plants, Native (*Phragmites*) (M, M)	**Research** Better quantification of rate of spread; more experimental evidence of effects on nutrient cycling and fish habitat, and to disentangle the effects of the invasion from the effects of salt hay farming, tide restriction, ditching, and other often associated disturbances. More information on the effects of the invasion in non-tidal systems.

Stressor (Overall Rank, Uncertainty)	**Needs**
Native Animals (deer and geese) (M,M or M-L)	**Research** Deer – determine harvest levels that avoid potential long-term ecological impacts to plant communities; document secondary impacts of herbivory on plants/animals. Geese – impacts to ecosystems including nutrient input to waterways, interspecific competition, and impacts to biodiversity.

SOCIO-ECONOMIC CONDITIONS

	Needs
All Stressors	Overall, suggested priorities for reducing uncertainties involve (1) Costs, (2) Job Losses, (3) Property Values, (4) Aesthetics, and (5) Worry (or psychological impacts), in that order. The order of priorities is a combined estimate of relative importance of these factors, the likelihood of progress on valid measurement and statewide monitoring of these impact categories, and the probability that reduction of these uncertainties would make a substantial difference to environmental management. An important initial task is to determine whether stressor-based estimates of socioeconomic impacts are the most useful for environmental management priority-setting. In some cases (e.g., hazardous waste sites), individual stressors are so mixed at particular sites or in their impacts (e.g., on worry) that it might be more worthwhile to conduct estimates on a site-based or other aggregate level. This decision will affect priorities for reducing socioeconomic uncertainties; the following list assumes a stressor-based definition.
General Cost Estimates	General methods for estimating costs, job losses, and property values are reasonably well developed, particularly for health impacts, even if still far behind methods for human health risk assessment. State government could ensure that expertise on these evolving methods is available in state, either at universities or on staff (e.g., of DEP). Improved estimates of health and ecological impacts (see Human Health and Ecological Quality suggestions above) will produce improvements in the socioeconomic estimates of those impacts' costs, job losses and property values as well.
Direct Costs	Costs due directly to stressor exposures (i.e., without prior health or ecological impacts), such as paint damage due to air pollution, are more problematic to estimate, although in most cases of lower magnitude than indirect costs via health and ecological impacts. Better methods to measure, or at least impute, the portion of all such costs attributable to environmental conditions (much less specific stressors) would be a great help. There is currently no systematic approach to monitoring such costs, either in New Jersey or elsewhere.

SOCIO-ECONOMIC CONDITIONS

Stressor (Overall Rank, Uncertainty)	**Needs**
Job Loss, Monitoring, & NJ specific data	Job losses due to environmental regulation have been a long-time focus of environmental economics, given the "jobs versus environment" debate. Insuring that this emphasis within the state is expanded beyond regulatory effects to the effects of changes in environmental conditions at the margin overall would be helpful, as would institution of a monitoring system.
Property Value Impacts	Property value impacts are unlikely to occur as widely across stressors as do costs or job losses, so they have a lower priority. Distinguishing environmental contributions to property value gains and losses is still in its infancy, and there is no systematic effort to track these contributions. Measures that can distinguish the impacts of aesthetics and worry on property values from the impacts of more direct environmental contributions would be particularly useful.
Aesthetic Impacts	Aesthetic impacts apply to even fewer stressors, and are likely to evoke considerable variability in response (particularly for visual insults). However, people who believe they suffer from such impacts are likely to rate them as very undesirable. Emerging technologies and research methods offer the potential of standardizing estimates of such impacts, but considerable support will be needed to develop and systematically apply such methods, so that these impacts get the attention they deserve.
Worry/ Psychological Impacts	Methods for measuring psychological impacts (i.e., "worry" as defined for this project) are better developed than methods for dealing with aesthetic impacts. There is as yet little standardization in these measures, nor in which kinds of impacts are worth attention (e.g., the kind that can be assessed relatively quickly, but are perhaps transient, versus more serious but rarer impacts that need in-depth assessment). No system currently exists for assessing psychological impacts regularly and systematically across the state and across different stressors. The existing literature suggests that a variety of factors (e.g., sense of personal control over the threat; degree of trust in environmental managers; [sometimes] knowledge about the risk or control methods) affect worry judgments. It is not yet known to what degree attempts to improve (for example) people's generic sense of personal control over threats, versus dealing with their sense of control over a particular environmental threat, would reduce such impacts.

SOCIO-ECONOMIC CONDITIONS

Stressor (Overall Rank, Uncertainty)	**Needs**
Other Socioeconomic Impacts	There are numerous socioeconomic impacts that occur but are not easily measured, including loss of social capital, diminished quality of life, and decreased peace of mind. This project did not attempt to develop any measures of these impacts due to limited resources and lack of scientific consensus on best approaches. Further research on measurement strategies would be immensely valuable.
Stressor-specific Research Needs (examples; see Appendix 5 for more)	**Brownfields** The following data would be helpful to provide a rigorous measurement of reductions in property value due to brownfields: 1. The amount of acreage in New Jersey considered "brownfields." 2. Number of residential and commercial properties within one-quarter mile of a brownfield and the current assessed value of this land. 3. More precise accounting of property value losses due to nearby contamination. 4. More knowledge about the health effects of brownfields. **Lead** It would be useful to conduct econometric research on property values that includes the presence of environmental lead as an independent variable in a hedonic regression. **Land Use Change** Data needed to better quantify the following socioeconomic impacts of land use change: · Aesthetic impacts · Psychological impacts · Consumers' preference for suburbs **Radon/Radium** Data Needs: 1. Non-fatal cancers attributed to radon and treatment costs. 2. Fatal and non-fatal cancers attributed to radium and treatment costs. 3. Numbers of houses (radon) and industrial sites (radium) at risk in New Jersey. 4. Number of houses/buildings that have been mitigated or remediated. 5. Sales prices of homes with high levels; number mitigated. 6. Surveys of individual level of worry related to radon and radium. 7. Work time lost due to illness caused by radon and radium.

Trend

Which problems are getting worse?

Which problems are getting better?

"Trend" in these assessments refers to the overall direction of change in the impact of the stressor during the next five years. As such it reflects an informed prediction which is subject to uncertainties in future policies and actions. Many stressors were judged to have no significant trends at all; in those cases, there is no evidence demonstrating that the stressor or its effects are increasing or decreasing. These stressors have relatively low impacts, and tend to vary somewhat from year to year and place to place. Microbiological stressors for the most part fall into this category. Even while exposure and infection rates are difficult to quantify, it is unlikely that the presence of these organisms in the environment is either increasing or decreasing over time.

About 40% of the problems evaluated show unquestionable improvements. Notably, improvements can be seen in the groups of chemical stressors, which account for about two thirds of the positive trends. As these are the targets of most environmental regulations, perhaps it's not surprising that the presence of chemicals has been declining in recent years. More stringent emissions requirements, chemical bans, and ongoing waste site cleanups have all contributed to lower levels of chemical contamination in New Jersey. Most of the air pollutants associated with automobile and power plant emissions are decreasing. These include carbon monoxide, butadiene, benzene, MTBE, and sulfur dioxide. Secondary problems such as ozone formation and acid precipitation are also showing improvement. Significant progress has also been made in reducing the impacts of secondhand tobacco smoke, in part due to smoking restrictions but also because fewer people are choosing to smoke. The incidence of floatables (beach and shoreline litter) has declined dramatically since New Jersey initiated its Operation Clean Shores program.

On the other hand, many stressors are likely to have impacts that remain unchanged or clearly get worse. Unlike chemical pollutants, many biological and physical stressors are unregulated and largely uncontrolled. These stressors include land use change, along with associated increases in habitat loss, habitat fragmentation, impervious surfaces, and water use. Other stressors are often compounded by these changes. Opportunistic pests such as geese and starlings, as well as a long list of invasive plants, tend to flourish in disturbed habitats, outcompeting other native species for food and nesting sites. Controlling these biological stressors presents its own unique set of challenges, while controlling the impacts of human development requires a prudent balancing of costs, benefits, and diverse human values. Traditional regulatory responses are not well suited to these kinds of consideration.

For some issues, determination of a single trend is difficult. In the case of lead, there are clear improvements in terms of human health risk, due to extensive education, screening, and remediation efforts. However, since lead continues to be released to the environment, ecosystems and wildlife are potentially at increased risk.

Whether or not these identified trends persist depends on a number of factors. Any improvements in air pollution achieved via better emissions controls will be offset by future increases in fuel consumption and energy use. Policy decisions, particularly at the local level, will largely determine the rate and extent of land use change and thus its potential for environmental degradation. Identifying and filling in data gaps may help target priority problems, potentially resulting in dramatic improvements. The NJCRP Steering Committee recommends increased monitoring with respect to issues with potentially worsening trends, to help focus resources where they will provide the greatest benefit (see Recommendations, beginning on page 89). The suggested monitoring, data analysis, and research priorities (page 61), as well as the full analyses from which these suggestions were drawn, offer an agenda for reducing data gaps before the next NJCRP is undertaken.

The summary on the following page is taken from the section on "potential for future changes in the underlying risk from this stressor" from the analytic template (Appendix 2), collapsing the 7-point scale used there into better, same, and worse trend judgements.

Table 7. Trend

TREND	HEALTH	ECOLOGICAL	SOCIOECONOMIC
Better	1,3-butadiene Arsenic Benzene Carbon monoxide (CO)-outdoor and indoor Chromium Cryptosporidium - drinking water Dioxins/furans Disinfection byproducts ELF/EMF Lead Lyme Disease Mercury MTBE Nitrates/Nitrogen in Water Noise Ozone (ground level) PCBs Pesticides - food Pesticides - outdoor Pesticides - water Radon Secondhand tobacco smoke Sulfur oxides VOCs-carcinogenic VOCs-noncarcinogenic West Nile virus	Asian longhorned beetle Arsenic Channelization Dioxins/furans ELF/EMF Floatables Hemlock woolly adelgid Inadvertent animal mortality Overharvesting (marine) Ozone (ground level) PCBs Pesticides-historical use Pesticides-present Petroleum spills Road salt Tin	1,3-butadiene Acid precipitation Arsenic Benzene Carbon monoxide (CO) Chromium Deer Dermo and MSX parasites in oysters Dioxins/furans Disinfection byproducts Floatables Lead Mercury MTBE Overharvesting (marine) Ozone (ground level) PCBs Pesticides Petroleum spills Radon Road salt Secondhand tobacco smoke Sulfur oxides Tin VOCs West Nile virus
Same	Acrolein Airborne Pathogens Cadmium Cryptosporidium -recreational water Formaldehyde Greenhouse gases Hanta virus Indoor microbial air pollution Legionella Nickel Nitrogen oxides PAHs Particulate matter Pesticides - indoor Pfiesteria Radionuclides Radium Waterborne pathogens (recreational water and drinking water)	Acid precipitation Blue-green algae Chromium Deer Dredging EHD virus in deer Green/red tides Habitat fragmentation Habitat loss Increased impervious surface Mercury MSX parasites in oysters Nickel Nitrogen pollution Off road vehicles PAHs Pets as predators Pfiesteria Phosphorus Phthalates QPX parasite in shellfish Starlings Thermal pollution VOCs Zinc	Acrolein Cadmium Catastrophic radioactive release Cryptosporidium Dredging EHD virus in deer ELF/EMF Formaldehyde Green/red tides Hanta virus Inadvertent animal mortality Indoor asthma inducers Indoor microbial air pollution Legionella Malaria and encephalitis Nickel Nitrogen pollution PAHs Particulate matter Pfiesteria Phosphorus QPX parasite in shellfish Radium Thermal pollution
Worse	Endocrine Disruptors Indoor Asthma Inducers Ultraviolet Radiation	Brown tide Cadmium Catastrophic radioactive release Copper Dermo parasite in oysters Endocrine disruptors Geese Genetically modified organisms (GMOs) Greenhouse gases Invasive plants Lead Light pollution Noise Ultraviolet radiation Water overuse West Nile virus Zebra mussels	Asian longhorned beetle Brown tide Copper Endocrine disruptors Geese GMOs Greenhouse gases Hemlock woolly adelgid Invasive plants Land use change Light pollution Off road vehicles Pets as predators Noise Starlings Ultraviolet radiation Waterborne pathogens Water overuse Zebra mussels

Catastrophic Potential

For most stressors, the impacts which are occurring, or may occur in the future, are relatively constant. However, for a minority of stressors, there exists a low probability for acute, widespread impacts far beyond the day to day, or average, level of risk. In contrast with stressors for which there is a continuous, more or less estimable level of exposure, these stressors also have a characteristic potential for large-scale, severe impacts to human or ecological health that cannot be predicted using standard risk assessment models. Catastrophic potential was not taken into account in the rankings; this information is provided for those readers who might wish to do so in setting their own priorities.

Catastrophic impacts are typically associated with accidents. Catastrophic radiation releases from nuclear power plants, and petroleum spills are obvious examples of potentially catastrophic stressors (note that the Human Health TWG decided that routine releases of radionuclides from nuclear reactors were a more pertinent stressor than catastrophic releases). Pesticides and endocrine disruptors were also judged to have potentially catastrophic impacts as a result of individual or institutional misuse or carelessness.

There are a number of biological stressors that were judged to have potentially catastrophic impacts to ecosystems. The MSX parasite, which infests and kills oysters, has caused massive die-offs in the past, and continues to present a threat. Brown tide, a recurrent seasonal algae bloom, has been occurring more frequently and lasting longer in recent years. The extent of the damage that may be caused by more severe bloom events is unknown.

Human activity may also bring about potentially catastrophic effects. Large-scale land use changes may increase the potential for damaging floods. Commercial harvesting of the horseshoe crab for bait has depleted that population to the extent that migratory bird populations are negatively affected by the reduction in crab eggs as a food source.

For a very few stressors, there is so much uncertainty that catastrophic effects are included within a wide range of potential impacts. Much of the concern associated with genetically modified organisms (GMOs) centers on the highly uncertain, but possibly severe, ecological consequences.

Table 8. Catastrophic Potential

	Health	Ecological	Socioeconomic
H	Greenhouse gases Pesticides-indoor	Brown tide Hemlock woolly adelgid Inadvertent animal mortality Petroleum spills	
MH	Pesticides-outdoor	Impervious surface	
M	Endocrine disruptors	Overharvesting (marine) MSX parasites in oysters Zebra mussels	Asian longhorned beetle Catastrophic radioactive release Cryptosporidium Endocrine disruptors Genetically modified organisms(GMOs) Land use change Petroleum spills Pesticides
ML	Particulate matter	Asian longhorned beetle QPX in shellfish	

Note: Stressors with Low catastrophic potential are not listed.

Populations At Risk

Technical Working Groups described for each stressor any populations or entities at "increased risk." The risks from a given stressor may be greater for certain individuals, species, or places for a number of reasons. They may be more likely to become exposed than the general population. They may be exposed to greater concentrations of the stressor, or are exposed more frequently. Or they may be more susceptible to the stressor's effects than other people or ecosystems.

Equity demands that differences in impacts are minimized to the extent feasible, and consistent with the goal of reducing impacts overall. "Increased" risk is relative only to the estimated statewide risk for that particular stressor, and does not imply anything about the seriousness of the risk. So while certain individuals or places may be deemed at "increased risk," the absolute risk level from that particular stressor can still be quite low. Thus, any population-specific risk should be carefully considered within the overall risk picture, to avoid undue focus on a subset of potentially less significant risks.

Human Health

Because they are still developing, children and the unborn are at increased risk from the health effects of a number of stressors, particularly chemicals. Their immature immune systems also place them at increased risk from disease-causing organisms. The elderly, and people with existing health problems, are also more susceptible to the effects of environmental stressors. Asthmatics, for example, are at increased risk from several stressors that aggravate this condition and trigger additional episodes. Note that these groups are no more likely to become exposed than the general population, but they are more likely to experience health effects as a result. Groups cited here do not include those (such as with genetic predispositions to certain diseases) for whom we lack enough information to provide a reasonable basis for protection above and beyond that given to an average New Jersey citizen. Knowledge may advance enough to include them in the next comparative risk report. Notable subpopulations at increased risk are highlighted in Table 9 below.

Table 9. Selected Subpopulations at Increased Risk for Health Effects

Children
Acrolein
Arsenic
Extremely low frequency/electromagnetic fields
Endocrine disruptors
Greenhouse gases
Indoor asthma inducers
Lead
Lyme disease
Mercury
Nitrogen oxides (NO_X)
Ozone (ground level)
Particulate matter
Pesticides
Polychlorinated biphenyls (PCBs)
Polycyclic aromatic hydrocarbons (PAHs)
Secondhand tobacco smoke
SOx
Waterborne pathogens

Fetuses
Disinfectant byproducts
Endocrine disruptors
Mercury
Waterborne pathogens

Elderly
Greenhouse gases
Particulate matter
Waterborne pathogens
West Nile virus

People with Asthma
Indoor asthma inducers
Nitrogen oxides (NO_X)
Ozone (ground level)
Particulate matter
Sulfur oxides (SO_X)

People with Immune Disorders
Airborne pathogens
Cryptosporidium
Legionella
Waterborne pathogens

People with Chronic Lung/Cardiovascular Disease
Greenhouse gases
Noise
Ozone (ground level)
Particulate matter

Increased health risk may also stem from an increased risk of exposure. Individuals living near sources of stressors are at greater risk than those at greater distances. Urban populations are at increased risk from the effects of many types of stressors as a result of their proximity and more constant exposure. Personal behaviors can also affect the degree of risk—smokers, for example, are at increased risk from radon, particulates, and PAHs. Special populations or geographic areas at increased risk are noted in the "What's at Risk?" section of each stressor summary.

Table 10. Locations with Elevated Health Risks

Location		Stressor
Urban Areas		1,3-Butadiene Acrolein Benzene (highly traveled roads) Indoor Asthma Inducers Nitrogen Oxides PAHs (in air)
Suburban/Rural Areas		Lyme disease
Rural/Agricultural Areas		Pesticides in ground water (shallow wells)
Counties		
Atlantic		Mercury (private wells)
Bergen		Carbon Monoxide; West Nile Virus*
Burlington		Carbon Monoxide
Camden		Sulfur Oxides
Essex		Sulfur Oxides (likely); VOCs-carcinogenic (acetaldehyde)
Gloucester		Sulfur Oxides
Hudson		Chromium (particularly Jersey City); West Nile Virus*
Hunterdon		Lyme disease
Middlesex		VOCs-carcinogenic (acetaldehyde)
Monmouth		West Nile Virus*
Morris		Lyme disease; Sulfur Oxides; West Nile Virus*
Ocean		Mercury (private wells)
Passaic		West Nile Virus*
Somerset		Lyme disease
Union		Carbon Monoxide; Sulfur Oxides
Warren		Lyme disease
Water Areas	Recreational	Cryptosporidium (freshwater); Waterborne Pathogens (marine or freshwater)
	NY/NJ Harbor Estuary	Dioxin (in crabs and lobsters, particularly Newark Bay)
	Coastal Areas	Greenhouse gases; Ozone (ground level);Ultraviolet Radiation
	Flood Zones	Greenhouse gases
	Kirkwood-Cohansey Aquifer	Mercury (private wells, mostly Ocean and Atlantic counties—see *Counties*); Radium (private wells) Radium
Northeastern NJ	Newark Basin (10 North-Central NJ counties)	Greenhouse gases (ground level ozone)

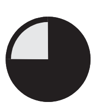
* Note that it is not possible to determine the exact geographic area where the individuals were bitten by the infected mosquito.

Ecosystems

Four stressors were consistently rated high or medium-high for all five ecosystems studied. These stressors included habitat loss, habitat fragmentation, increased impervious surface, and ultraviolet radiation, which were discussed in the statewide ranking. The following paragraphs describe other stressors that were ranked highly for individual ecosystems. Valuable additional information can be garnered by examining risks and trends on an ecosystem or regional basis, as in the following figures.

High Risks to Inland Waters

The tendency for some compounds to accumulate in sediments increases their risk to aquatic ecosystems. Chemical stressors such as PCBs, mercury, and lead accumulate in aquatic sediments, resulting in increasingly severe reproductive and developmental effects throughout the food chain. Wildlife at the upper levels, such as raptors, may experience severe reproductive effects, including reproductive failure. Endocrine disruptors such as phthalates may also cause reproductive effects in aquatic ecosystems. Inland lakes are particularly susceptible to the effects of phosphorus, since excessive levels of this nutrient are introduced via urban and agricultural runoff, causing excessive plant and algae growth. Overabundance of Canada geese also creates disproportional impacts to inland lakes, affecting the natural balance of species and contributing to excess nutrient levels with their droppings.



Medium-High

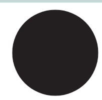
Worse	Geese
Worse	Lead
Worse	Phosphorus
Same	Mercury
Same	Phthalates
Better	Pesticides (historic use)
Better	Polychlorinated biphenyls (PCBs)

Figure 6. High risks to inland waters

High Risks to Marine Waters

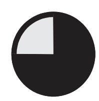
Like inland waters, marine ecosystems are also at greater risk from compounds that accumulate in the water column and bottom sediments, such as endocrine disruptors, pesticides, mercury and lead. Nitrogen, acting as the saltwater equivalent of phosphorus, similarly alters nutrient levels in marine ecosystems, causing the excessive growth of some algae, which can become toxic.

Some of the most significant risks to marine waters are stressors that affect only marine waters. The duration and severity of the seasonal algal bloom known as brown tide has worsened in recent years. Blooms, which reduce light penetration and growth of submerged plants, affect the availability of suitable habitat for a variety of fish and shellfish species. The diamondback terrapin, the only species of turtle in the United States that inhabits saltwater marshes, is accidentally killed at alarming rates. Thousands are inadvertently drowned in crab pots or killed by vehicles each year. Overharvesting, using the example of the horseshoe crab, also ranks very highly among stressors to marine ecosystems.



High

Worse	Brown tide
Better	Overharvesting (marine)



Medium-High

Worse	Lead
Same	Endocrine disruptors
Same	Nitrogen pollution

Figure 7. High risks to marine waters

High Risks to Wetlands

As with the other aquatic ecosystems, wetlands are similarly affected by persistent chemical stressors such as PCBs and phthalates. Estuarine wetlands are also at increased risk from the adverse effects of petroleum spills. Inland wetlands and saltwater estuaries are also at increased risk from the effects of nutrients, with phosphorus having the greatest impacts on freshwater wetlands and nitrogen resulting in adverse effects on estuaries. Invasive plant species, especially purple loosestrife and phragmites, are becoming increasingly dominant in wetlands. The effects of the resulting reduction or elimination of other native plants is potentially irreversible and affects a variety of wetland-dependent wildlife. Deer and the hemlock woolly adelgid, an insect pest that poses a catastrophic threat to hemlock stands, also rank high in impacts to wetland ecosystems. As noted above, there is high inadvertent mortality for diamondback terrapins in saltwater marshes.

Medium-High	*Worse*	Invasive plants
	Worse	Phosphorus
	Same	Deer
	Same	Nitrogen
	Same	Phthalates
	Same	Petroleum Spills
	Better	Hemlock woolly adelgid
	Better	Inadvertent animal mortality
	Better	PCBs

Figure 8. High risks to wetlands

High Risks to Forests

Biological stressors pose the highest risks to forest ecosystems. The hemlock woolly adelgid is an insect pest that has already infested more than 90% of New Jersey hemlock forests. Once infested, trees rarely recover. Among the impacts associated with a loss of hemlock trees are an increasing risk of forest fires, changes in forest nutrient cycles, and loss of rare species habitat. Invasive plants are also judged to present a high risk to forest ecosystems. Often sold as ornamentals, non-native species of trees and shrubs can invade forest ecosystems, displacing native species upon which wildlife are dependent. Increasing densities of white-tailed deer and starlings also create significant impacts to forest health by altering the balance and diversity of woodland communities, by limiting recruitment and disrupting natural successional dynamics.

High	*Same*	Deer
	Better	Hemlock woolly adelgid
Medium-High	*Same*	Starlings
	Worse	Invasive plants

Figure 9. High risks to forests

High Risks to Grasslands

As with forest ecosystems, the overabundance of white-tailed deer is among the highest risks to grassland ecosystems. The number of deer in the state has doubled in the past twenty years, and the ecological impacts associated with their browsing are exacerbated by ongoing rates of suburban development. Residential areas and parks tend to create "deer refuges" where the animals can rapidly increase their numbers in the absence of hunting or natural predators. Historically used pesticides (e.g., DDT and chlordane) are also a concern due to their persistence and adverse effects on wildlife.

Medium-High	*Same*	Deer
	Better	Pesticides (Historic Use)

Figure 10. High risks to grasslands

The following table (Table 11) lists stressors deemed to have "high" or "medium-high" impacts on particular ecosystem types in particular watershed management areas (see map for their locations). As with other rankings, the scoring was based on readily available data, literature, and professional judgment. The robustness of the scoring is highly stressor-specific (e.g., for individual impacts on a watershed there is a sound basis for ranking impacts of brown tide or hemlock woolly adelgid, but less for statewide stressors such as lead or invasive plants). Peer reviews were conducted for statewide rankings only, not for these watershed-level rankings.

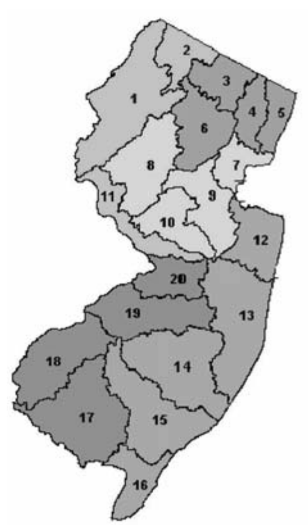


Figure 11. Watershed Management Regions

Table 11. Stressors with High or Medium-High Impacts on Watersheds

	Upper Delaware	Passaic	Raritan	Atlantic	Lower Delaware
Inland Waters	Catastrophic radioactive releases Geese Habitat fragmentation Habitat loss Increase in impervious surface Pesticides-present use Zebra mussels	Arsenic (M-H) Catastrophic radioactive releases Chromium (M-H) Copper (M-H) Geese Habitat fragmentation Habitat loss Increase in impervious surface Lead (M-H) Mercury (M-H) PAHs (M-H) PCBs (M-H) Pesticides-present use Zebra mussels	Arsenic Catastrophic radioactive releases Copper (M-H) Geese Habitat fragmentation Habitat loss Increase in impervious surface Lead (M-H) Mercury (M-H) PAHs (M-H) PCBs Zebra mussels	Catastrophic radioactive releases Copper (M-H) Geese Habitat fragmentation Habitat loss Increase in impervious surface Mercury (M-H) PCBs (M-H) Water overuse (M-H) Zebra mussels	Catastrophic radioactive releases Geese Habitat fragmentation Habitat loss Increase in impervious surface Water overuse (M-H) Zebra mussels
Marine Waters		Catastrophic radioactive releases Chromium Copper (M-H) Dioxin Dredging Endocrine disruptors Habitat fragmentation Habitat loss Increase in impervious surface Lead (M-H) Nitrogen Mercury PAHs	Catastrophic radioactive releases Copper (M-H) Dioxin (M-H) Endocrine disruptors Habitat fragmentation Habitat loss Increase in impervious surface Lead (M-H) Nitrogen Mercury PAHs (M-H) Petroleum spills Tin (M-H)	Catastrophic radioactive releases Brown tide Habitat fragmentation Habitat loss Overharvesting (marine) Inadvertent animal mortality Increase in impervious surface Lead (M-H) Nitrogen	Catastrophic radioactive releases Dermo parasite in oysters Endocrine disruptors Habitat fragmentation Habitat loss Overharvesting (marine) Inadvertent animal mortality Increase in impervious surface Lead (M-H) Nitrogen
Wetlands	Catastrophic radioactive releases Deer Garlic mustard Geese (M-H) Habitat fragmentation Habitat loss Increase in impervious Japanese honeysuckle (M-H) Phthalates Purple loosestrife Phragmites Multiflora rose (M-H) Norway maple (M-H) Tree-of-heaven (M-H)	Catastrophic radioactive releases Chromium Copper (M-H) Deer Garlic mustard Geese (M-H) Habitat fragmentation Habitat loss Increase in impervious surface Japanese honeysuckle (M-H) Multiflora rose (M-H) Mercury (M-H) Norway maple (M-H) PAHs Phthalates Phragmites Purple loosestrife Tree-of-heaven (M-H)	Arsenic (M-H) Catastrophic radioactive releases Copper (M-H) Deer Garlic mustard Geese (M-H) Habitat fragmentation Habitat loss Increase in impervious surface Mercury (M-H) Multiflora rose (M-H) Norway maple (M-H) PAHs (M-H) Petroleum spills Phragmites Phthalates Purple loosestrife Tree-of-heaven (M-H)	Catastrophic radioactive releases Deer Garlic mustard Geese (M-H) Habitat fragmentation Habitat loss Overharvesting (marine) Inadvertent animal mortality Increase in impervious surface Nitrogen Phragmites Phthalates Purple loosestrife Tree-of-heaven (M-H) Water overuse (M-H)	Arsenic (M-H) Deer Garlic mustard Geese (M-H) Habitat fragmentation Habitat loss Overharvesting (marine) Increase in impervious surface Inadvertent animal mortality Phragmites Phthalates Purple loosestrife Nitrogen Tree-of-heaven (M-H) Water overuse (M-H)
Grasslands	Catastrophic radioactive releases Habitat fragmentation Habitat loss	Catastrophic radioactive releases Habitat fragmentation Habitat loss	Catastrophic radioactive releases Habitat fragmentation Habitat loss	Catastrophic radioactive releases Habitat fragmentation Habitat loss	Catastrophic radioactive releases Habitat fragmentation Habitat loss
Forests	Asiatic bittersweet Catastrophic radioactive releases Deer Garlic mustard Habitat fragmentation Habitat loss Hemlock woolly adelgid Increase in impervious surface Japanese barberry Japanese honeysuckle Multiflora rose Norway maple Tree-of-heaven	Asiatic bittersweet Catastrophic radioactive releases Deer Garlic mustard Habitat fragmentation Habitat loss Hemlock woolly adelgid Increase in impervious surface Japanese barberry Japanese honeysuckle Multiflora rose Norway maple Tree-of-heaven	Asiatic bittersweet Catastrophic radioactive releases Deer Garlic mustard Habitat fragmentation Habitat loss Hemlock woolly adelgid Increase in impervious surface Japanese barberry Japanese honeysuckle Multiflora rose Norway maple Tree-of-heaven	Asiatic bittersweet Catastrophic radioactive releases Deer Garlic mustard Habitat fragmentation Habitat loss Hemlock woolly adelgid Increase in impervious surface Japanese barberry Japanese honeysuckle (M-H) Multiflora rose Norway maple Tree-of-heaven	Asiatic bittersweet Catastrophic radioactive releases Deer Garlic mustard Habitat fragmentation Habitat loss Hemlock woolly adelgid Increase in impervious surface Japanese barberry Japanese honeysuckle (M-H) Multiflora rose Norway maple Tree-of-heaven

Aquatic life, wildlife, plants and whole ecosystems are at increased risk from a variety of stressors, particularly chemicals. Persistent chemicals, as well as metals such as lead and mercury, remain in the aquatic environment for long periods of time. Contaminants may bioaccumulate in the food chain, reaching higher concentrations in the tissues of fish and the animals that consume them, and resulting in increased risk.

For many stressors, birds represent a population of concern. Forest-breeding birds have been identified as among those at increased risk from habitat loss and fragmentation. Healthy bird populations require large expanses of uninterrupted forest canopy; as these forest "patches" decrease in size, the more adaptable birds become more prevalent and species diversity is reduced. Fish eating birds and mammals are at increased risk from a number of chemical stressors as well (e.g., mercury, pesticides, and PCBs). Not only are they exposed to high concentrations of persistent stressors through bioaccumulation, they are also highly susceptible to reproductive effects as a result of that exposure.

Terrestrial plants and trees are also at increased risk from a number of stressors. In addition to direct impacts due to habitat loss, stressors such as invasive plants and deer reduce plant community biodiversity and lead to secondary impacts (e.g., reduced breeding bird diversity). Due to their habitat requirements, amphibians are at increased risk due to habitat loss and habitat fragmentation. Mammals are at increased risk due to contaminants including lead and pesticides.

Specific ecosystem types may also be at increased risk from particular ecological stressors. For example, sensitive, high quality ecosystems such as the Pinelands may be at greater risk from the effects of chemical stressors such as acid precipitation, and from habitat disturbances.

Table 12. Examples of Wildlife and Ecosystems at Increased Risk

Aquatic Plants and Bottom-Dwelling Animals
Arsenic
Brown tide
Cadmium
Chromium
Copper
Dermo parasite in oysters
Dredging
MSX parasites in oysters
Nitrogen pollution
Pesticides
Polycyclic aromatic hydrocarbons (PAHs)
Overharvesting (marine)
QPX parasite in shellfish
Water use/overuse
Zinc

Fish and Shellfish
Cadmium
Dioxin
Harmful algae
Nitrogen pollution
Petroleum spills
Pesticides
Phosphorus

Birds
Electromagnetic fields
Floatables
Habitat fragmentation
Habitat loss
Lead
Light pollution
Mercury
Noise
Overharvesting(marine)
Petroleum spills
Pesticides
Pets as predators
Polychlorinated biphenyls (PCBs)
Starlings

Pinelands
Acid precipitation
Habitat loss/fragmentation
Mercury

Amphibians
Habitat loss
Habitat fragmentation

Terrestrial Plants and Trees
Acid precipitation
Deer
Habitat loss
Hemlock woolly adelgid
Invasive plants

Mammals
Catastrophic radioactive release
Electromagnetic fields
Lead
Pesticides-current use

Socioeconomic

The socioeconomic assessments focused on damage costs imposed by stressors, as well as risks to property values, employment, aesthetics, and psychological well being. In the many cases where medical costs drove the risk estimate, populations at increased risk tend to follow the human health effects. Thus, special populations at increased socioeconomic risk will often include children, the elderly, and people with existing health problems.

Low-income residents are at increased risk from a number of stressors as a result of the higher prevalence of the conditions that result in exposure. The risks from lead, for example, are increased in older buildings that have not been renovated—lower income residents are more likely to occupy these homes. Urban residents may also be at increased risk for property value impacts due to their proximity to brownfields and other sources of chemical waste. Urban residents may also bear a disproportionate share of damage costs and loss of value associated with certain stressors.

Even while statewide risks were judged to be low, some stressors may cause significant problems in the communities where they occur. This is true for a number of stressors to shore and coastal environments. Residents in coastal areas and lakeshore communities may be at increased risk from negative employment or property losses due to localized aesthetic impacts, such as those associated with floatables or algal blooms.

Table 13. Examples of Groups and Areas at Increased Socioeconomic Risk

Children
Cryptosporidium
Lead
Mercury
Nitrogen oxides (NO_X)
Ozone (ground level)
Particulate matter
Pesticides

Elderly
Legionella
Ozone (ground level)
Particulate matter
Pesticides

People with Asthma
Nitrogen oxides (NO_X)
Ozone (ground level)
Particulate matter

Low-Income Households
Indoor asthma inducers
Lead
Noise
Pesticides
Radon
Secondhand tobacco smoke

Urban Areas
1, 3-butadiene
Dioxins/furans
Formaldehyde
Radium

Coastal Areas/Shore Communities
Floatables
Greenhouse gases
Green/red tides
Particulate matter
Petroleum spills

Rankings by Socioeconomic Dimensions

In the process of developing overall rankings, the Socioeconomic TWG produced ratings of how each stressor affected individual dimensions (e.g., Property Values or Aesthetics) of socioeconomic conditions. These ratings were correlated but distinctive enough to be of potential interest. Inferred rankings below use the same thresholds (e.g., between High and Medium-High) as for the overall SE rankings; stressors with Low rankings are omitted due to lack of space.

Table 14. Rankings by Socioeconomic Dimensions

Property Values	Employment	Costs	Aesthetics	Worry
High Land use change	**High**	**High** APs Arsenic STS IAI Land use change Lead Ozone Particulates UV	**High** Deer Land use change Lead Particulates Pesticides Phosphorus Sulfur oxides	**High** EDs IAI Land use change Lead Pesticides Ultraviolet radiation
Medium-High Noise	**Medium-High** Arsenic Invasive Plants Land use change	**Medium-High** 1,3-butadiene Acrolein Deer Dioxins/furans Formaldehyde IAM Invasive plants Pesticides Petroleum spills PCBs Radon Water overuse WPs	**Medium-High** STS Light pollution Petroleum spills	**Medium-High** Arsenic Dioxins/furans PCBs PAHs
Medium 1,3-butadiene Acrolein CRR Deer Lead Pesticides PCBs Phosphorus	**Medium** Dermo parasites in oysters PCBs	**Medium** Acids CO CRR Dermo parasites in oysters DBPs Dredging EDs Mercury Nickel Nitrogen oxides Phosphorus PAHs VOCs	**Medium** HWA IAM ELF/EMF Noise Overharvesting PCBs VOCs	**Medium** CRR Deer GGs IAM Noise Particulates Petroleum spills Water overuse
Medium-Low Floatables Radon Water overuse	**Medium-Low** Chromium Floatables Mercury	**Medium-Low** Channelization Chromium Cryptosporidium Floatables Geese HWA Sulfur oxides West Nile virus Zebra mussels	**Medium-Low** Channelization Chromium Floatables Geese GRT MTBE Off-road vehicles Ozone (ground level)	**Medium-Low** Chromium Cryptosporidium STS Floatables GMOs Mercury MTBE ELF/EMF Radon West Nile virus Zebra mussels

Definitions:

APs=airborne pathogens
CO=carbon monoxide
CRR=catastrophic radioactive release
DBPs=disinfection byproducts
EDs=endocrine disruptors
STS=secondhand tobacco smoke
ELF/EMF=extremely low frequency/ electromagnetic fields
GGs=greenhouse gases
GMOs=genetically modified organisms
GRT=green and red tides
HWA=hemlock woolly adelgid
IAI=indoor asthma inducers
IAM=inadvertent animal mortality
MTBE=methyl tertiary butyl ether
PAHs=polycyclic aromatic hydrocarbons
PCBs=polychlorinated biphenyls
UV=ultraviolet radiation
VOCs=volatile organic compounds
WPs=waterborne pathogens

Major Sources of Stressors

TWGs were asked to identify the relative contribution of various primary (e.g., business, agriculture) and diffuse (e.g., sediment, biota [living creatures]) sources to the levels of stressors in the New Jersey environment. The aim was to provide very general guidance to those interested in opportunities for risk reduction, particularly where a single strategy might be able to reduce the levels of multiple stressors simultaneously (see Recommendations section). Note that even for stressors defined exactly the same, it can be reasonable for different TWGs to rate the importance of stressors differently. For example, golf courses (Recreational) are not a significant source of arsenic exposures for people, but they are for wildlife. However, more detailed analysis will be needed to identify particular strategies that might be effective in reducing stressor levels. The parenthetical information on large business sources for health stressors shows the additional detail available in some analyses, but this level of detail was not systematically assessed for all stressors.

Table 15. Sources That Are "High" or "Medium-High" for Listed Stressors

SOURCES	HEALTH	ECOLOGICAL
Primary Sources Large Business/Industry	**H:** Airborne pathogens (composting facilities, sanitary landfills, wastewater treatment plants), Benzene (manufacturing and solvent use; vehicular petroleum use, including construction equipment), Extremely low frequency/electromagnetic fields (broadcasting and communications, microwave ovens, MRI and medical diathermy machines, radio-frequency arc welders, etc.), Endocrine disruptors (pharmaceuticals, consumer products), Greenhouse gases (power plants), M-H: NOx (utility and large industry external combustion units), SOx (large utility boilers), VOCs -carcinogenic (ethylene oxide, fumigants in food industry; acetaldehyde, combustion products in chemical industry)	**H:** Acid deposition (sulfur emissions from coal-burning power plant), Arsenic (coal -fired utilities, past pesticide manufacturing), Asiatic Bittersweet (horticultural/landscape), Cadmium (smelting, plating), CR radiation (nuclear power industry), Chromium (chromate ore processing, electroplating, metal finishing, production of stainless & heat-resistant steels, production of refractory products, pigment production, leather tanning, textile manufacturing), Copper (electronic, and electrical industries, water purveyors), Extremely low frequency/electromagnetic fields (electricity producers & users), Impervious surface (land development), Japanese Barberry (ornamental shrub for landscaping), Japanese Honeysuckle (residential landscape), Lead (construction for tank linings, piping, equipment handling corrosive gases & liquids, x-ray & atomic radiation protection, manufacturing metal alloys, paints & pigments, ceramics, lead storage batteries), Mercury (energy & heat production, products containing mercury, management of mercury-containing waste), Oil spills (oil transport, lightering, and transfer), Ozone (NOx & hydrocarbon emissions), PAHs (industrial chemical wastes such as coal tar, petroleum refinery sludges, waste oils & fuels & wood treating residue, heat & power generation, controlled refuse incineration), Phragmites (filling for construction activity), Phthalates (used in production of household & consumer goods), VOCs (automobile emissions, by-product of reactions among compounds in the air, sewage treatment plants, stormwater runoff), Water overuse (power generation)
Small Business/Industry	**H:** Benzene, Greenhouse gases, Air pathogens, Extremely low frequency/electromagnetic fields, Ozone (VOC), UV Radiation, Mercury (elemental-dental practices)	**H:** Arsenic, Cadmium, Chromium, Mercury, Lead, Copper, Overharvesting (marine), Inadvertent animal mortality, Water overuse, Pesticides-current use (aquatic herbicides, mosquito larvicides), Phthalates, Asiatic bittersweet, Impervious surface, Japanese Barberry, Japanese Honeysuckle, Purple Loosestrife, Phragmites
Transportation	**H:** 1,3-butadiene, Benzene, Greenhouse gases, Air pathogens (in a few carriers), Formaldehyde, MBTE, Ozone (VOCs, NOx), Particulates, PAHs M-H: Acrolein, Noise Pollution, VOCs (Non-carcinogenic)	**H:** Inadvertent animal mortality, Acid precipitation, Ozone, Road salt, PAHs, VOCs, Habitat loss, Habitat fragmentation, Impervious surface, Extremely low frequency/electromagnetic fields, Noise (overflights), Light, Zinc

Table 15. Sources That Are "High" or "Medium-High" for Listed Stressors - "continued"

SOURCES	HEALTH	ECOLOGICAL
Residential	**H:** Carbon monoxide, Greenhouse gases, Air pathogens (some homes), Endocrine disruptors, Secondhand tobacco smoke, Formaldehyde, Asthma inducers, Mercury (Elemental), Ozone (VOCs), Pesticides (indoors, outdoors, in water), Radium	**H:** Copper, Water overuse, Currently used pesticides (Aquatic herbicides, mosquito larvicides; Diazinon and similar pesticides), Norway Maple, Habitat loss, Habitat fragmentation, Increase in impervious surface M-H: Phosphorus
Agriculture	**H:** Endocrine disruptors, Mercury (inorganic-historical), Nitrates, Pesticides (on food, in water)	**H:** Arsenic, Copper, Zinc, Overharvesting (marine), Endocrine disruptors, Currently used pesticides (Oxamyl, Diazinon, synthetic pyrethroids, atrizine), Phragmites, Multiflora Rose M-H: Phosphorus
Recreation	**H:** Secondhand tobacco smoke, Asthma inducers, Noise pollution (occasionally), Pesticides (outdoors), Waterborne pathogens	**H:** Arsenic, Copper, Currently used pesticides (aquatic herbicides, mosquito larvicides), Dredging, Multiflora Rose, Noise (recreational and underwater), Light (depends on uses of communications towers)
Resource Extraction		**H:** Chromium, Overharvesting (marine), PAHs, Asiatic bittersweet, Japanese Honeysuckle, Inadvertent animal mortality
Government	**H:** Airborne pathogens (a few locations), Waterborne pathogens	**H:** Water overuse, Road salt, Currently used pesticides (mosquito larvicides, synthetic pyrethroids), Phragmites, Multiflora Rose
Natural Sources/Processes	**H:** Airborne pathogens, Indoor Microbial air pollution, Legionella, Radon (air, water), UV Radiation, Hanta virus M-H: Arsenic	**H:** Arsenic, Copper, Water overuse, PAHs, Asiatic bittersweet, Norway maple, Tree of Heaven, Garlic mustard, Japanese barberry, Japanese honeysuckle, Phragmites, Multiflora rose, Brown tide
Orphan Contaminated Sites	**H:** MTBE M-H: Chromium, PAHs	**H:** Dioxin (case specific), Phragmites, Copper
<u>Diffuse Sources</u> Sediment Sinks	**H:** Arsenic (in specific locations), Cadmium, Endocrine disruptors, Mercury (methylmercury) M-H: PCBs	**H:** Endocrine disruptors, PCBs, Arsenic, Chromium, Mercury, Zinc, PAHs, Historic use of pesticides (DDT, Chlordane), Phthalates
Soil Sinks	**H:** Indoor microbes, Mercury (inorganic, methylmercury), Nitrates, Pesticides (indoors), Radium M-H: Lead	**H:** Arsenic, Chromium, PAHs, Historic use of pesticides (DDT, Chlordane), Purple Loosestrife, Japanese Stiltgrass, Multiflora Rose
Non-Local Air Sources (incl. deposition)	**H:** Greenhouse gases, Mercury (methylmercury), Particulates M-H: Nitrogen oxides in air, PAHs	**H:** Mercury, PAHs, Phthalates, Chromium
Groundwater sinks	**H:** Radium	None
Biota Sinks	**H:** Cadmium, Cryptosporidium, Legionella, Mercury (inorganic, methylmercury), Pesticides (food), PCBs, Waterborne pathogens, Hanta virus M-H: Endocrine disruptors	**H:** Historic use of pesticides (DDT, Chlordane), Phthalates

Types of Stressors

Another way to examine these results is to consider the kind of stressor that is involved. The following pages discuss the relative impacts of biological, chemical and physical stressors.

Biological stressors are microorganisms, plants, or animals that can affect human health, ecosystems, or social and economic conditions. Bacteria, molds, parasites, and viruses are common biological stressors that may pose a risk when present in large enough numbers in surface water, drinking water, and indoor air. Parasites and toxins may result in large-scale mortality of fish, shellfish, and other wildlife. Excessive amounts of algae (algal "blooms") are another common type of biological stressor. Blooms such as brown tide reduce sunlight necessary for other species' survival, and some forms of algae can be toxic. Invasive plants include "exotic" species (plants introduced accidentally or intentionally to this area) as well as native species that thrive in disturbed soils. Invasive plants typically outcompete other species, destroying habitat and disrupting established food webs. Excessive numbers of insects and animals can cause adverse impacts.

Along with its socioeconomic benefits, industrialization has resulted in large quantities of chemicals in New Jersey's air, land, and water. In fact, it is the chemical stressors group that most people have come to associate with human-caused environmental damage. A number of chemicals are released as byproducts of combustion processes in automobiles, waste incineration, and power generation. Secondary problems associated with these include acid precipitation, climate change, and ground-level ozone. Organic and inorganic chemicals that are intentionally introduced to attain a desired environmental impact include pesticides and fertilizers (phosphorus and nitrogen), road salt, and antibiotics. Environmental tobacco smoke (also known as secondhand smoke) is considered a chemical stressor for this report. Metals, typically released to the environment via industrial processes and uncontrolled waste sites, include cadmium, chromium, copper, lead, mercury, tin and zinc. Naturally occurring chemicals, such as arsenic, may also pose a risk when present in harmful quantities in ground water used for drinking.

Physical stressors affect human health or habitat quality through mechanisms other than a biological or chemical agent. Radiation damages or destroys living tissue by breaking chemical bonds, causing reactions among biological molecules, and producing mutations in DNA. Excess noise and light are also physical stressors that can have adverse effects on both humans and wildlife. Ecosystems are increasingly undermined by physical stressors. When a forest is cleared for development, associated habitat is fragmented or lost, resulting in losses of native species. Similarly, when the course of a river is changed for flood control or navigation, existing habitats are altered or eliminated. Physical stressors also include those arising from individual or commercial activity that has negative effects on ecological populations: floatables (litter), inadvertent animal mortality, off road vehicles, and overharvesting. Finally, issues related to water quantity and temperature are considered within this category.

Biological Stressors

Microorganisms

All of New Jersey is exposed to potentially harmful microbiological stressors from time to time. Contact with bacteria, fungi, molds, and parasites in the air or water generally produce no adverse effects, either because the organism is not generally infectious, because the number of organisms is below the infectious dose, or because the body's immune system effectively counters the infection. However, in some cases exposure can produce mild to serious respiratory and gastrointestinal illness. Most cases are mild, and the majority are not reported, thus risk estimation is difficult. While no more likely to become exposed, asthmatics and others with pre-existing health problems are at greater risk for developing more serious symptoms. New Jersey has had no confirmed cases for over a decade of *Giardia or Cryptosporidium,* two of the environmental pathogens which have evoked the greatest concern nationwide. West Nile virus, which is transmitted by mosquitos, has on rare occasions caused severe illness or death, but most infections produce no symptoms. On the other hand, New Jersey ranks among the top five states in the nation for documented cases of Lyme disease, with more than 2,000 cases annually. Lyme disease is treatable, but can result in serious long-term health problems if undiagnosed. Trends in risks from microorganisms are likely to remain fairly stable. While the number of cases may vary from year to year, the long-term incidence of microbiological illness is not anticipated to change significantly.

Microbiological risks to New Jersey ecosystems are considered low. With the exception of the Dermo and MSX parasites' catastrophic reduction of the oyster population over the past few decades, wildlife mortality associated with microbiological infection is not considered to be a significant or widespread threat.

Plants

Plant stressors are primarily an ecological concern in New Jersey, although toxic algae can result in minor human health problems as well. Historically, algal blooms have occurred in specific locations and at times of the year when conditions are conducive to a bloom event. Brown tide blooms appear to be occurring more often and lasting longer; more research is needed to determine the impact of natural and human influences on algae populations. Invasive plants threaten native species and ecosystems. These species tend to outcompete native species, reducing biodiversity and the availability of important food sources for wildlife. Invasive plants spread vigorously in disturbed habitats, so stressors that promote habitat degradation and alteration will also exacerbate the risks from invasive plants. Moreover, many species of invasive plants continue to be sold as ornamental species, creating an ongoing source of new infestations. The risks from genetically modified organisms (GMOs) continue to be debated within the scientific community and the likelihood and magnitude of adverse effects remain uncertain.

Animals

There are no human health impacts associated with the vertebrate and invertebrate animal stressors evaluated. As with invasive plants, ongoing urbanization promotes an increasing dominance by nuisance animal species. Geese and starlings thrive in suburban landscapes, crowding other species and congregating in massive flocks. Pets also threaten wildlife, particularly songbirds and nesting shorebirds. Residential development results in a loss of habitat compounded by an associated increase in pet populations. In addition to preying on birds and small rodents, cats can also outnumber and outcompete wild predators such as hawks. A small number of stressors have the potential for catastrophic impacts to New Jersey ecosystems. The hemlock woolly adelgid is an insect pest that has already affected most of New Jersey's hemlock stands, and unless an effective predator is introduced will eventually infest and ultimately destroy them. Although there are no known infestations in New Jersey forests, the Asian longhorned beetle, if introduced, could pose a serious threat to hardwood species, especially maples. Finally, zebra mussels will inevitably become established in New Jersey. When this occurs, freshwater aquatic ecosystem dynamics will be dramatically altered as has been the case in the 20 or so states invaded to date.

Chemical Stressors

There are two general types of effects resulting from chemical contamination of the New Jersey environment. Acute effects generally occur during or shortly after relatively brief exposure to high levels of a chemical. Accidental spills or misuse of pesticides, petroleum, or industrial chemicals are typical scenarios resulting in acute effects. In New Jersey, these acute events are rare and not the main factor behind the ranking of most chemical risks. The other types of effects are those that result from long term exposure to lower concentrations of contamination. These chronic effects can result from contamination of water, soil, sediments, air, or food. The effects themselves are less easily pinpointed to specific contaminants except in cases where particular chemicals have unique effects, which, e.g., is the case with lead poisoning of children. The field of risk assessment is largely focused on the chronic effects of chemical contaminants and most of the reported risk in New Jersey is from populations exposed to low levels of these pollutants.

Products of combustion

Intentional burning of fossil fuels in vehicles, boilers and industrial facilities leads to the emission of several compounds. In the cases of ozone, NOx, carbon monoxide, particulate matter, formaldehyde, and acrolein, combustion is the primary path for release into the environment. In all of these cases, the effects are the result of inhalation and the primary effect is on the respiratory system. Some individuals are particularly sensitive to these airborne contaminants, including asthmatics, individuals with cardiovascular disease and the elderly. Ozone remains a high human health risk in New Jersey while other combustion products result in medium or medium-low risks. Ecosystems are not significantly affected, although the long term exposure to these pollutants may be a stress. These combustion products have been the focus of significant regulation and in most cases their impacts have been decreasing, but recent increases in the combustion of fossil fuels may result in future increases in effects.

Benzene and some volatile organic compounds (VOCs) are released from fuel transfer or from incomplete combustion. They can cause respiratory problems or cancer when breathed in, through drinking water.

Contaminants of fossil fuels, including sulfur (leading to SO_X), mercury and, historically, lead, also cause health and ecological problems typically through deposition. Once these contaminants reach the soil, they are either directly toxic (lead) or alter soil and water chemistry (SO_X) or undergo chemical changes where they enter the food chain (mercury). In the cases of lead and SO_X, regulation has led to significant reduction but the persistence of lead in soil results in continuing high socioeconomic and human health risks. For mercury, regulations are more recent and the concentrations in the environment are still causing significant ecological and human health risks.

Other organic chemicals

Organic chemicals include a wide range of chemical classes and the potential toxicologic effects on humans and ecosystems are diverse. In some cases, such as PCBs, dioxin and some historic-use pesticides, the chemical properties include long term stability which has resulted in continuing impacts on humans and ecosystems. This contributes to these chemicals posing high or medium-high impacts to human health (dioxin) or ecosystems (PCBs and historic-use pesticides). Chlorine-containing VOCs are often significant cancer-causing agents and pose medium-high risks to human health.

Secondhand tobacco smoke does not fit easily into any category because it includes a mix of contaminants. Regardless of its classification, however, such smoke poses great risk to New Jerseyans' health.

Finally, it should be noted that of the tens of thousands of chemicals in existence, only a few types or examples were able to be evaluated as part of the NJCRP.

Metals and inorganic chemicals

Metals and inorganic chemicals do not degrade over time and New Jersey is suffering the effects from historic use. These effects are particularly pronounced in aquatic environments, where toxic metals such as mercury, lead, chromium, tin, and nickel pose significant ecological risks.

Phosphorus and nitrogen are continually being added to aquatic environments. They pose medium risks to ecological systems because they supply nutrients to algae where resulting population increases can cause oxygen depletion and shift the balance of species to those requiring less oxygen. The nature of these risks to aquatic systems that are valued for aesthetic and recreational purposes leads to high socio-economic risks.

General effects

It is difficult to identify the impacts to the environment from individual chemicals because of the co-existence of many different contaminants resulting from many different sources across wide areas.

However, there is some evidence of general chemical contamination. Toxic sediments contribute to the reduction of species richness in most New Jersey urban river environments. A significant percentage of foods are contaminated with pesticides. Drinking water from both surface and ground water sources may contain chemical contamination. Fortunately, the level of contamination of food and public drinking water is almost always lower than the standards that are developed to protect human health. The situation with toxic pollutants in air may suggest greater risk. The EPA's National Air Toxics Assessment suggests that several pollutants exceed benchmark levels and the criteria pollutants (especially ozone and particulates) remain at levels known to affect human health. Drinking water from private residential wells is in some cases also a source of elevated risk, because of the shallow depth of most private wells and the historical tendency for private wells to remain untested in the absence of specific known contamination (starting in 2002 private wells must be tested when a real estate transfer occurs).

For almost every air pollutant, the concentration indoors is greater than the concentration outdoors, and for almost every New Jersey citizen, the time spent indoors is greater than the time spent outdoors. The combination of these two factors results in the risks from indoor air pollution generally being greater than outdoor pollution.

Physical Stressors

By far the greatest risks to New Jersey ecosystems are the group of physical stressors relating to land-disturbing activities. The continued expansion of suburban development exemplifies large-scale land use changes that foster increasing rates of habitat fragmentation and loss, impervious surface cover, inadvertent animal mortality, light and noise pollution, and water overuse. Development pressure continues statewide, and remaining high quality habitats, such as the Pinelands, Highlands, and Cape May regions, are at greater risk than existing urbanized areas. The disturbance or loss of large expanses of forested and wetland areas results in a significant decline in native plants and animals, dramatically alters hydrologic flow patterns and water quality, and promotes over-population of disturbance-tolerant nuisance species of plants and animals. While there are few studies documenting the specific effects of land use changes on New Jersey species, the ecological impacts of habitat alteration are well documented, as are the extent and magnitude of land use change in the state. Returning developed land to an undeveloped condition is not likely to be practical on a large scale. However, New Jersey has restricted development in over 3 million acres of protected land, over 900,000 of which have been permanently protected as open space. In light of human population and economic pressures, New Jersey faces a continuing challenge in effectively slowing the rate of development-related impacts to ecosystems.

A number of stressors in this category relate to radiation. Exposure to radiation in any form increases the risk of a variety of cancers. There are scientific uncertainties regarding the effects of very low doses of radiation as well as the numbers of people in the state that may be exposed to unhealthy levels. Reductions in stratospheric ozone may have contributed to an increased incidence in skin cancers in human populations, and changes in ecosystem dynamics stemming from the effects of excess UV radiation on plankton. Several thousand cases of skin cancer are attributed to ultraviolet radiation each year.

Naturally-occurring levels of underground radium and radon also contribute to excess cancer cases in New Jersey—radon levels are primarily responsible for an estimated 1,400 lung cancers. Risks from sources of radiation are likely to decline over time, as people control their exposures to UV radiation and have their homes tested and remediated, if necessary, for radon. Electromagnetic fields are a type of radiation without the potential to cause cancer directly. The health impacts from exposure to this kind of radiation are highly uncertain.

Because the majority of available monitoring and research dollars has been directed at chemical stressors, there remains a great deal of uncertainty regarding the risks of many physical stressors. As a result, an apparent lack of evidence for ecological effects does not necessarily mean there are none. Off-road vehicles, noise, light, floatables, and channelization are examples of physical stressors on fish and wildlife that have not been systematically researched. Additional data have the potential to shed new light on any of these issues, and risks may appear lower than they actually are.

Steering Committee Findings and Recommendations

SC - Recommendations

There is a wealth of information in the reports from the Technical Working Groups. Much of this information is going to be useful for specific policy discussions over the next several years. The Steering Committee focused on stressors that ranked high on more than one TWG's ranking or that appeared to be relatively neglected, and on themes that deserve consideration for New Jersey's future environmental management. Other stressors ranked high by a single work group remain important even if they are not in the following findings. Four general classes of environmental threat were identified.

Key Findings

Land use change lies at the heart of many of New Jersey's environmental problems, particularly those related to ecological health.
Not only does land use change cause direct impacts to habitat by the conversion of natural lands to human development, and the fragmentation of contiguous ecosystems necessary for migration and to maintain sufficient territories for large mammals, but indirect effects on ecological systems result in tipping the balance of several of the state's ecosystems. For example, changing land use can cause an increase in the amount of paved surface and rooftops, resulting in increased stormwater flows into New Jersey streams and rivers. In areas with undisturbed vegetation, rain and snow melt percolates more slowly into surface soils. These soils remove contaminants, and the resulting water either enters subsurface aquifers or seeps into streams without eroding soils. Increased human development has led to a greater interaction between deer and people with increased automobile accidents and damage to ornamental plants. Land use change particularly harms older communities, by skewing employment patterns and reducing property values, while brownfields (contaminated urban areas) take land off of the development market. As a result, development takes place instead in undeveloped areas, requiring new infrastructure and spreading undesired impacts more widely.

Physical transformation of the landscape in New Jersey deserves much more attention and action to minimize undesirable impacts while addressing basic needs for housing and quality of life. This stressor, in experts' views, produced, by far, the largest negative ecological <u>and</u> socioeconomic impacts. This conclusion reinforces the growing belief among many New Jersey citizens and organizations that converting forest and farm land to commercial and residential use creates major problems for the quality of ecological systems and human life in the state. There is an enormous challenge in determining how to reduce these negative effects without losing substantive benefits or creating new problems. New Jersey has already developed and revised the State Development and Redevelopment Plan and the Sustainable State initiative; set up the Sustainable State Institute; encouraged brownfields redevelopment; and increased purchases of open space by state and local governments. But these efforts still fall far short of what is needed merely to prevent further deterioration, much less to begin reducing these impacts. The Steering Committee did not evaluate whether recent policy proposals, by such groups as New Jersey Future or the Coalition for Affordable Housing and the Environment, are the best way to go; this was not part of its mission. However, the high negative impacts confirmed by the Comparative Risk Project should motivate the state and other environmental managers to strengthen their efforts to reduce or avoid these impacts.

Indoor pollution problems were among the highest threats in both the health and socioeconomic analyses, and deserve more attention from environmental and public health managers. Several stressors ranked as having "high" human health risk are primarily or entirely problems of indoor air pollution: secondhand tobacco smoke (STS), radon, indoor asthma inducers, carbon monoxide, and indoor microbial air pollution. Formaldehyde and several volatile organic compounds (VOCs) may pose indoor exposures of concern, although there is insufficient evidence to quantify the risk. In addition to the increased concentrations of indoor pollutants, average New Jersey citizens spend most of their time indoors. This can result in exposures to pollutants several-fold higher from indoor conditions as compared to outdoor conditions, even though it should be noted that outdoor sources are major contributors to indoor problems for some pollutants (e.g., VOCs).

Indoor air as a significant health risk suggests a major opportunity to improve human health with a common indoor-air strategy. Currently, with few exceptions (radon; secondhand tobacco smoke in public spaces), indoor air pollutants are not only unregulated, but are subject to no systematic attempt to address them through such other means as monitoring or education. The rationale for a lack of programmatic effort toward dealing with such issues has been the absence of legislative authorization and appropriations for government action, in turn due to a perceived lack of positive mandate for regulation of privately-owned indoor spaces, particularly private residences. But several indoor spaces are publicly owned (e.g., schools), or subject to regulation despite private ownership (e.g., day care facilities), or targets of environmental education (e.g., indoor radon). The New Jersey Department of Health and Senior Services has been concerned enough about public health implications of indoor air pollution to begin discussion of an action plan. The Steering Committee calls for a partnership of DEP and other environmental managers with DHSS to examine systematically indoor air pollution's impacts and management options, and to take action against these problems. All policy tools should be considered, including education, market incentives, and a command-and-control regulatory approach. The current approach, with inconsistent attempts at education and persuasion for some pollutants, is clearly not sufficient for the magnitude of the problem.

Other serious indoor health problems involve skin contact or ingestion, particularly for children, rather than air pollution. These pollutants include lead and indoor use of pesticides. Although both situations have improved—lead has been banned for use as a gasoline additive and in paint; the more dangerous pesticides have been banned and commercial applicators of pesticides must be certified—there is still room for improvement. This is particularly the case, again, for in-home exposures, for which education and/or remediation efforts are still weak.

Invasive species pose a serious ecological threat to several New Jersey ecosystems. Invasive plants—comprising purple loosestrife, Norway maple, and garlic mustard, plus seven other plants analyzed here and hundreds more not analyzed—threaten biodiversity and ecological integrity in several ecosystems. Wetlands are a particular concern, but invasive plants thrive wherever disturbed soil is found, which is often the result of land use change. The Asian longhorned beetle is an example of a problem insect, which destroy forests in New Jersey if not for so far vigilant control efforts. The hemlock woolly adelgid has damaged more than 90% of the state's hemlock forests. The 2002 upswings in the southern pine beetle (in its first-ever appearance in New Jersey, currently ravaging Cape May and the Pinelands) and the gypsy moth are other examples of problem insects. The zebra mussel has already destroyed freshwater ecosystems in over a dozen states, and this thumbnail-sized mollusk is likely to reach New Jersey within five years.

Several outdoor contaminants continue to pose health risks, despite progress in reducing outdoor air pollution, remediating brownfields, and removing lead from gasoline. Examples include ground-level ozone and nitrogen oxides in air, and lead and other pollutants remaining in urban soils. Further progress in these areas will be difficult, given such obstacles as the regional and global contributions to New Jersey air pollution, and the funding and liability problems still associated with site remediation.

Next steps

In addition to the four highlighted classes of environmental issues, the Steering Committee identified some directions for future policy discussions that should be based on the technical information included in this report.

Addressing many of these problems will require partnerships among agencies of state government. Environmental health threats indoors are certainly shared interests of DEP and DHSS, and the New Jersey Department of Community Affairs also might play an important role. Partnerships with the New Jersey Departments of Agriculture and Transportation can constructively address other issues; school-related problems (from energy use to integrated pest management) can be dealt with in partnership with the New Jersey Department of Education.

These are only a few examples of potentially helpful partnerships. Given the importance of these problems, DEP should take the lead in suggesting briefings for other cabinet officers, and in scheduling regular cross-agency meetings to advance action on these problems.

Dealing with the significant environmental problems created by land use changes will require DEP to take a lead role in working with the new Office of Smart Growth and the Smart Growth Policy Council, as well as with local planning officials.

The DEP should partner with DHSS and other appropriate organizations to systematically examine impacts and management options for dealing with indoor environmental problems (both air pollution and others), and to take action against these problems. There will be challenges to moving beyond the current limited focus on education and persuasion for just some of these pollutants. A particularly difficult problem is addressing pollution inside private residences, since the tradition has been to have the home-owner take responsibility. However, there is precedent for government involvement even here (e.g., in building codes), homeowners clearly need help in dealing with such problems, and the Steering Committee believes that government, in partnership with others, can produce creative solutions.

Clearly there is insufficient information about several environmental threats; increased monitoring, data assessment and research may help design and implement effective risk reduction strategies. Several stressors pose known risks but the sources of pollutants are uncertain and the identification of geographic or demographic population areas at risk is incomplete. Monitoring programs may help the state focus resources in geographic areas or economic sectors that will provide the greatest benefit, as in tracking invasive species and certain air pollutants. Trend judgments by the experts also offer a basis for making these decisions. For example, potentially worsening trends for such problems as global climate change, zebra mussels, and genetically modified organisms imply that certain areas or types of impacts deserve to be targeted for monitoring to provide an early warning in case impacts may threaten human or ecological health. More research on some issues will help in understanding future policy options. Although for many stressors sufficient data were available to give experts great confidence in their judgments of relative impact, this was not true in all cases. For example, indoor asthma inducers and pesticides ranked high in both health impact and uncertainty; research to clarify interactions of asthma causes and monitoring to determine the extent of indoor pesticide exposure would be helpful. Among stressors with high ecological impact, the ratings of historical-use pesticides were highly uncertain; monitoring of bird and water concentrations and research on endocrine disruption and immunity effects are needed. Several other stressors (such as Cryptosporidium, pets as predators and extremely low frequency radiation, among others) received "Low" overall scores for human health or ecological impacts, but the ranking was highly uncertain.

We are not recommending that priority setting and stressor reduction must await resolution of these uncertainties. Impact reduction opportunities might be effective and efficient even in the face of uncertainty; "paralysis by analysis" is not our intention. However, where existing management options are difficult or expensive to implement, with serious doubts about whether they will actually reduce net environmental impacts, targeted research and monitoring can be a vital step toward identifying the best actions.

A high priority should be placed on identifying and targeting sources that produce multiple stressors. Stressors that co-occur (i.e., come from the same sources, often as the result of identical processes) offer the potential for more effective environmental management, since strategies directed at reducing emissions of one of these stressors may in many (but not all) cases reduce the others as well. Air pollutants are one example where a set of stressors (e.g., "greenhouse" gases promoting global climate change; outdoor air pollutants; air toxics) can be jointly reduced by single actions (e.g., more efficient energy use; alternative fuels; emission reductions technology). Even if some of the affected stressors rank low in relative impact, a focus on tackling common sources can still maximize the reduction in impacts from a given expenditure of resources and time. Although DEP and the private sector are already doing this to some extent for air pollutants, this approach can be emphasized, and extended to other areas (e.g., curbing the spread of invasive plant species). As part of its mandate, NJCRP was asked to identify the sources of stressors, a less detailed version of the source allocation of pollutants in the Netherlands green plans. The result (see pages 72-73) is not sufficient for such targeting but does provide a useful first step.

State officials and New Jersey's Congressional delegation should seek assistance from the federal government in dealing with sources originating outside New Jersey borders and other problems that can benefit from federal assistance. Criteria air pollutants, such as NO_x (also a precursor to the criteria pollutant of ground-level ozone) and SO_x, blown into the state to exacerbate locally-derived air pollution, and pollution of water bodies (e.g., New York-New Jersey Harbor estuary, Delaware River) are well-known examples of this problem. Emission of "greenhouse gases" has global sources and global climate change impacts, and some invasive species (such as zebra mussels, not yet observed in New Jersey, but likely to appear in the next few years), are examples whose impacts have not yet occurred but also involve out-of-state sources. New Jersey has been trying to deal with transboundary air pollution for several years (e.g., in the Ozone Transport Assessment Group, active in the 1990s), and is the first state to set a numerical target for reducing its own emissions of greenhouse gases, in part as a means to set an example to others. New Jersey has a responsibility to take action on its own sources of these stressors. But federal legislation could stop the sales of invasive plants as landscaping ornamentals. Federal laws also could place restrictions on air pollutants, either through efficiency standards or reduced pollutant limits, as well as hold others accountable.

Several problems do not involve out-of-state sources, but can benefit from federal assistance. Changing land use may require a coordinated strategy combining local government zoning authorities, state agency funding priorities, and changes in federal policies to reduce dispersed development.

Uncertainties about basic mechanisms of stressor action (i.e., toxicology) require federal support for research, and New Jersey's Congressional delegation should ensure that the appropriate agencies (e.g., Environmental Protection Agency [EPA]; National Institutes of Health) have the necessary resources.

Local discussions of comparative risks may yield important new environmental protection efforts. Several environmental problems identified in this report will be difficult to manage at a state level. Varying local conditions, or the need to promote changes in behavior in a broad base of local citizens suggests that local discussions of relative risk could be productive in such areas as obtaining more local, detailed monitoring data or local planning leading to beneficial changes in land use decisions. Although this project reported geographic areas at particular risk where this information was available it focused on statewide impacts. Localities have environmental problems that may differ from statewide averages, and exploring what those are may help inform local governments' ability to set their own priorities.

A pilot local comparative risk project has begun in New Jersey as a collaboration between New Brunswick and Rutgers University. DEP's initial environmental partnerships with cities and counties and its watershed management efforts provide potential vehicles for further comparative risk project work at the local level. Making NJCRP analyses and rankings available on the World Wide Web, as planned, is an additional opportunity for fostering deliberation among New Jersey citizens about relative environmental impacts and priorities at all geographic and political levels.

NJCRP results should be used by DEP as part of its risk-based and performance-based management system, to ensure that the agency's goals, objectives, environmental indicators, and action priorities are addressing important opportunities to reduce negative environmental impacts.

DEP has made great progress in improving its ability to identify where progress in environmental quality is or is not being made, and whether its efforts are directed appropriately, since its strategic planning began in 1995. However, NJCRP analyses have the potential to add further insight, and the agency should take advantage of that opportunity.

The State should consider repeating NJCRP at regular intervals, because it is a strong and useful complement to topic- and program-specific analyses. DEP will review NJCRP's eventual contribution to the agency's strategic planning and to environmental progress before deciding whether to pursue another round of the Project. Our own experience has shown that the educational value of this exercise, for participants and audiences alike, is by itself reason to seriously consider repeating the NJCRP, and that its planning value will be demonstrated. EPA sponsored similar comparative risk projects for metropolitan areas, municipalities, tribes, and watersheds for several years, and their results consistently support our beliefs regarding its value as a complement to topic-specific and program-specific analyses.

Given the slow changes in environmental conditions and the time necessary to enact program changes through planning and implementation, we suggest that the Comparative Risk Project need not be repeated at the state level for at least ten years.